1995 RESEARCH HIGHLIGHTS

Air Force Office of Scientific Research
Bolling AFB DC 20332-0001

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Preface

This volume is the third annual issue of *Research Highlights* based on our monthly editions of significant achievements and accomplishments. Although this edition contains a small selection of AFOSR's many research successes in 1994, they are representative of our mission:

- to sponsor and sustain basic research
- to transfer and transition research results, and
- to support Air Force goals of control and maximum utilization of air and space.

The highlights provide brief descriptions of AFOSR's research investment accomplishments, examples of technology transfer, and technology insertion. Their purpose is to provide Air Force, DOD, government, and private sector officials interested in science and technology management with brief accounts illustrating how AFOSR supports the Air Force and DOD missions and the national posture in technology.

AFOSR 's integrated management approach fosters bilateral and multilateral partnerships between Air Force, university and industry researchers and Air Force, defense and commercial industrial customers. Last year, our nearly 2,000 active research tasks spawned more than 260 significant technology or product applications, more than one-half of these encompassed direct transfers to U.S. industry, with military as well as commercial benefits.

The diverse and wide-ranging scientific efforts in this volume share the common denominator of quality research. Some of the research highlighted here will find its way into currently deployed Air Force systems; some will not reach maturity until we enter the 21st century. These accomplishments demonstrate how, in consonance with its motto, "Building Partnerships with Excellence and Relevance," AFOSR fulfills its important role as a technology transition broker. With this vision, AFOSR continues to provide the Nation with the basic knowledge for new and advanced technologies to meet the challenges of the future.

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Directorate of Aerospace and Materials Sciences

Research Discovers Phenomenon Affecting Supersonic & Hypersonic Flight Performance

Researchers at North Carolina State University have discovered a new, and previously unknown mechanism which causes air breathing SCRAMJET engine inlets to "unstart" at supersonic speeds. The unstart condition is a process which causes an engine to shut down during flight. Air breathing engine inlet unstart on supersonic & hypersonic flight vehicles is a critical problem for the Air Force. Identifying the causes of this phenomenon will have a direct impact on the design, cost, and safety of future Air Force supersonic and hypersonic flight vehicle systems.

Under AFOSR sponsorship, the North Carolina State researchers performed the first turbulent flow computational fluid dynamics (CFD) simulations of maneuvering vehicle supersonic inlet flows. The maneuver prescribed was a constant, sustained pitch up motion through 30 degrees angle of attack. This is a gentle maneuver by today's standards, since aircraft routinely fly through angles of attack up to 60 degrees. The researchers discovered that the unstart process began through the turbulent boundary layer downstream of the inlet throat before the inlet reached one degree angle of attack. The inlet was fully unstarted at only five degrees angle of attack.

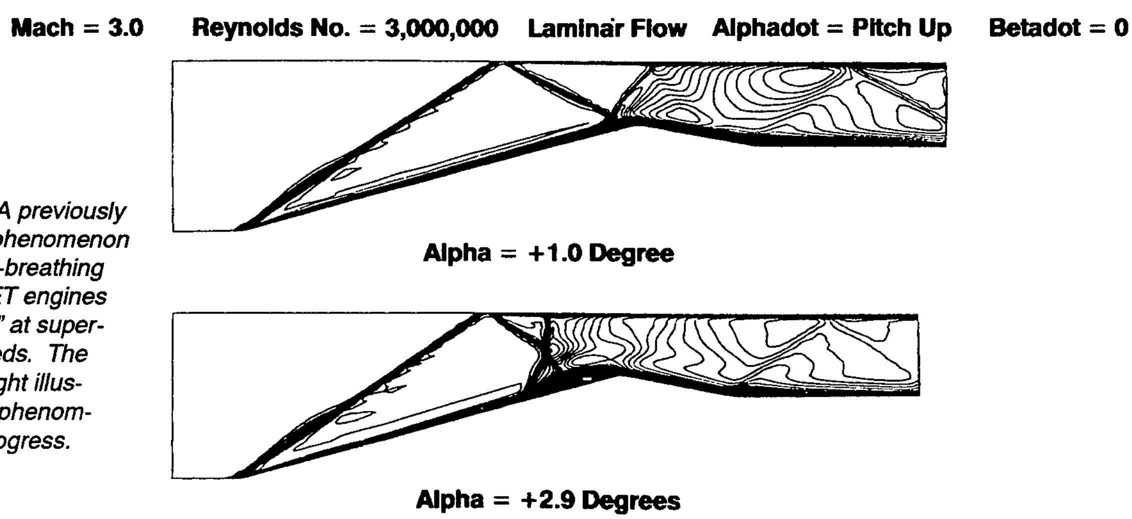

Figure 1. A previously unknown phenomenon causes air-breathing SCRAMJET engines to "unstart" at supersonic speeds. The figure at right illustrates this phenomenon in progress.

The High Speed Civil Transport (HSCT) program at the Boeing Commercial Airplane Group is working with the principal investigator at North Carolina State University, Dr. Scott McRae, to apply the research to their program. This research has already significantly aided the Boeing

HSCT engine inlet designers and directly impacted the design of normal shock stability systems for the HSCT. Future AFOSR research will investigate the effects of more complex, three-dimensional maneuvers on inlet unstart as well as mechanisms to control and prevent the occurrence of the problem.

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Discovery Increases High-Temperature Resistance Of Ceramics

Drs. Helen Chen and Martin Harmer of Lehigh University recently found that the high temperature mechanical properties of alumina (AL_2O_3) ceramic can be significantly increased by doping the material with small amounts of yttrium and lanthanum. This discovery will have a significant impact on both military and civilian applications since alumina is widely used in the chemical, metal cutting, electronic and other industries. This development can benefit the Air Force by producing better alumina fibers for use in composites, reducing machining costs for structural parts made of superalloys, and allowing the manufacture of less-costly electronic components.

The mechanical strength of materials at elevated temperatures is measured in terms of "creep rate," the rate of deformation under applied load. Among oxide ceramics, alumina is one of the most creep resistant materials, capable of withstanding temperatures up to 1700C. Chen and Harmer

2a **2b**

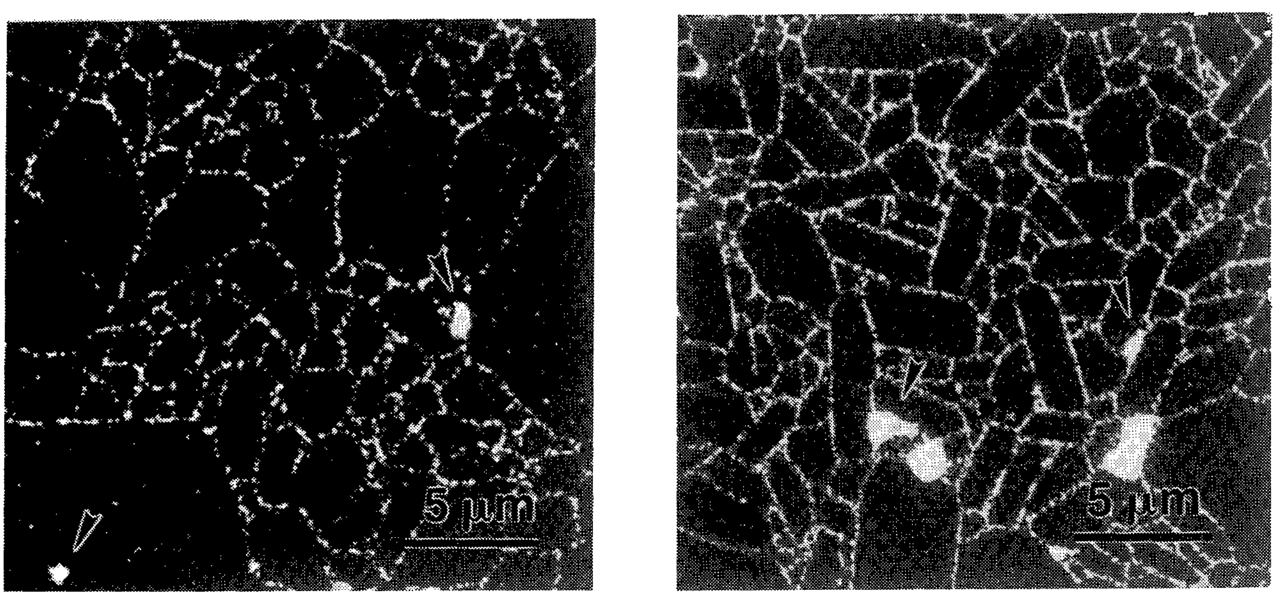

Figure 2. Drs. Helen Chen and Martin Harmer of Lehigh University showed that the high temperature properties of alumina ceramic can be dramatically improved when doped with small amounts of yttrium and lanthanum. These essential ingredients of the scientists work are shown by secondary ion mass spectroscopy (SIMS) images in figures 2a (yttrium) and 2b (lanthanum).

discovered that the addition of yttrium and lanthanum in quantities of only 1000 parts per million (in reference to aluminum) decreases the creep rate of alumina more than 100 times. This makes the material even stronger at high temperatures and increases the maximum temperature at which it can be used by 200 to 300 degrees. In addition to its immediate economic benefits, developing the fundamental understanding of this strengthening phenomenon paves the way for research to increase the service temperatures of many other ceramic materials.

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Laser Cladding Technique Is Superior to Traditional Metal Welding Methods

Professor Jyoti Mazumder of the University of Illinois has developed a new technique called "laser cladding" for the processing and repair of turbine engine components which was recently transitioned to industry. Applications of laser cladding include applying coatings to turbine airfoils and the welding and repair of turbine components during production. Mazumder's new technique will result in decreased production time and costs to the Air Force.

Professor Mazumder's technique uses a laser as the heat source instead of an electrical arc as in traditional processes such as tungsten inert gas (TIG) welding. The laser offers more precise control of the heat-affected zone and more rapid process control. Quantum Laser Corporation is using the new process to apply the hard face-coatings to low-pressure turbine blades. The laser cladding technique demonstrates a clear advantage over TIG welding by providing a 95% first-through processing yield and up to 99% final yield as compared to only 50% and 90% for TIG welding. General Electric Aircraft Engines is also using the laser cladding technique to attach turbine blade tips and repair components.

Several automotive companies are considering application of the technique because of its unique ability to apply a thin, metallic layer in a precise location. The primary use of laser cladding in the automotive industry would be to apply copper and nickel alloys on an aluminum engine block. The thin layer of copper and nickel alloy around the valve seat permits a much higher exhaust gas temperature thus improving fuel efficiency.

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Novel Fluid Thrust Vectoring Concept Promises Enhanced Maneuverability

In a collaborative fundamental study of the controllability of turbulent jet shear layers, Professor Anjaneyulu Krothapalli of Florida State University and Professor Paul Strykowski of the Univer-

Counterflow Thrust Vector Control

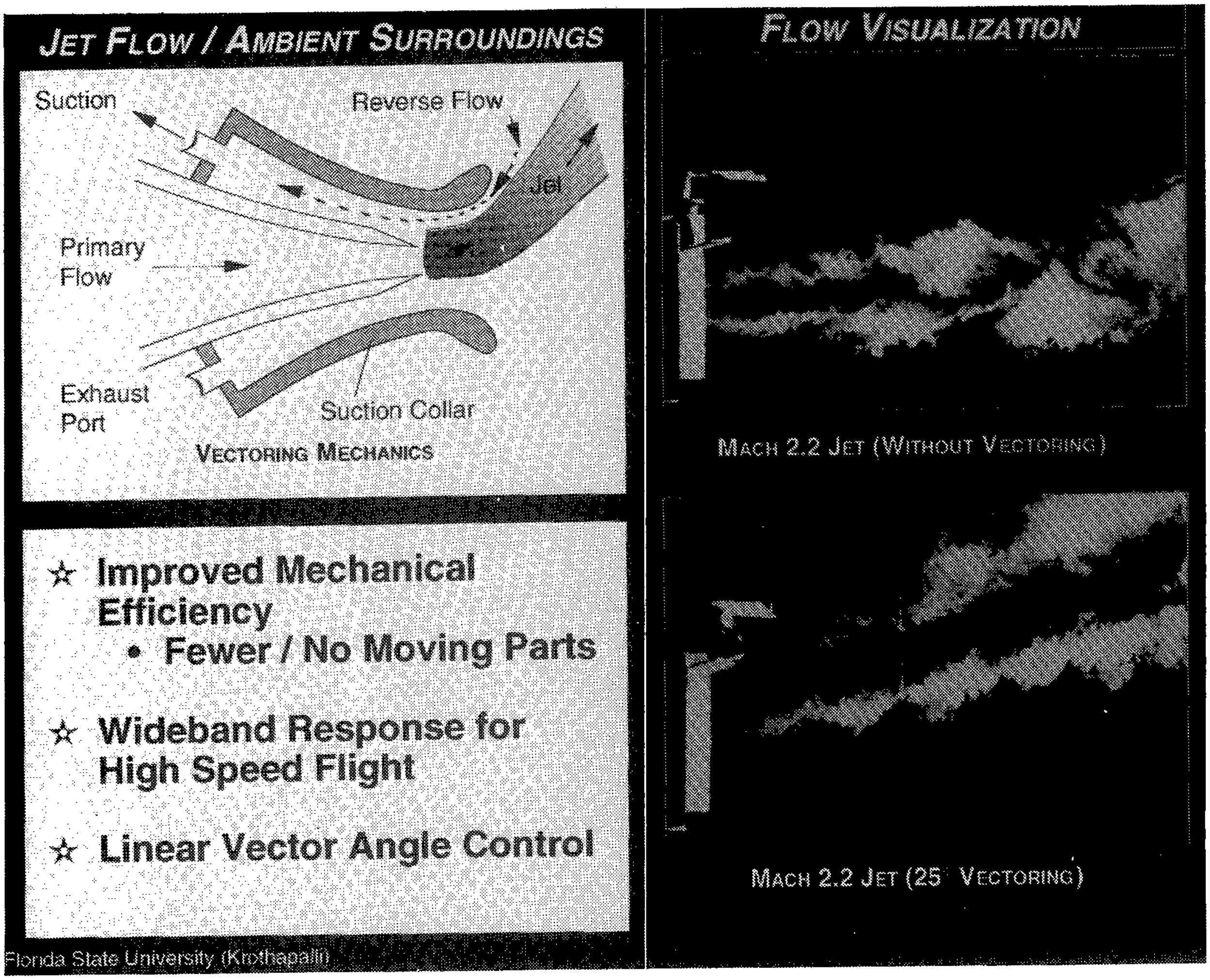

Figure 3. Thrust vectoring of a supersonic jet as achieved with a counter flow nozzle.

sity of Minnesota have developed a novel fluid thrust vectoring concept. Applying their concept to future fighter aircraft could result in drastic improvements in maneuverability and combat effectiveness.

Krothapalli and Strykowski found that by applying suction in an unsymmetric fashion near the lip of a supersonic jet nozzle, the jet could be made to "flip over" to one side, creating vectored thrust (Figure 3). They also found that, beyond a critical suction level, symmetry of the jet could be broken and the vectoring angle controlled continuously up to as much as 25 degrees at Mach 2.2. The energy required to provide the suction is only one percent of the total jet propulsion energy.

Krothapalli and Strykowski's technique may be explored for its potential to replace heavier and slower responding mechanical techniques such as the "paddles" used on the X-31. Drastic improvements in maneuverability and combat effectiveness have already been demonstrated in the X-31 program. The new technique raises the possibility of even more improvements in the program. The more sophisticated fluidic techniques could save costs and enhance the range and maneuverability of the next generation fighter by providing lighter-weight alternatives to the current techniques.

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New Wind Tunnel Device Permits Simulation of Unique Aircraft Maneuvers

Dr. Narayanan Komerath and doctoral candidate John Magill of the Georgia Institute of Technology's School of Aerospace Engineering have developed a new device to study rate-dependent aerodynamic interactions in the flows around rapidly maneuvering aircraft and missiles. The device, dubbed the Wind-Driven Manipulator, will allow the simulation of complex maneuvers in a wind tunnel environment and facilitate the design of more agile fighter aircraft with improved tactical combat capability.

Figure 4. John Magill and Dr. Narayanan Komerath of the Georgia Institute of Technology's School of Aerospace Engineering examine their Wind Driven Manipulator. The device will allow the simulation of complex aircraft maneuvers in a wind tunnel environment.

Simulating complex maneuvers in a wind tunnel environment and repeating them precisely requires manipulators that can simultaneously move an aircraft model rapidly about multiple axes, regardless of the loads experienced by the model. Conventional designs need powerful motors and heavy linkages to accomplish this, making the manipulator bigger than the model and extremely expensive to build and use. Also, the conventional designs are usually only capable of simple maneuvers such as pure pitch or roll in isolation. New, lightweight designs like Komerath and Magill's are needed to handle larger models under more realistic coupled maneuvers such as pitch-roll-yaw combinations. Komerath and Magill's ingenious yet simple design is based on the idea of using the energy of the wind tunnel freestream to help drive the manipulator at high rates. Their Wind-Driven Manipulator uses a lever arm to magnify the aircraft motion that is generated by airfoils mounted downstream of the model. Small servo motors and position sensors connected to a digital control system change the attitudes of the airfoils to achieve the desired motion about multiple axes simultaneously.

The initial studies using the manipulator seek to capture important flow features and relate them to the rates of coupled axis maneuvers. These studies will later be extended to more detailed, quantitative investigations using laser velocimetry. Force measuring capabilities will also be incorporated into the manipulator to help develop new flight control laws for the Air Force's next generation fighter which will employ unconventional control surface concepts. The manipulator technology is also being explored for commercial applications such as inexpensive pumping power for irrigation control. The researchers have recently applied for a patent on their device.

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New Method Developed to Produce Diamond Films

Professor Mark Cappelli and his colleagues at Stanford University have successfully employed an arc-jet engine in a chemical vaporization deposition method involving plasmas of either methane and hydrogen or acetylene and hydrogen. The arc-jet engines, developed for orbit transfer propulsion, can now be used to produce inexpensive diamond films which have a wide range of Air Force applications including high temperature and strength materials, corrosion resistant coatings, and semiconductors.

Capelli's group found that an arc-jet engine's electrical discharge breaks hydrogen atoms free. When the four hydrogen bonds in methane are broken, the carbon atom in the compound seeks electrons to fill the gaps in its outer shell. If the carbon atom then bonds to four other carbon atoms, diamond is created. In order to produce diamond films, a gas mixture must be activated to produce "precursor" molecules and then transported to a surface. Cappelli and his fellow researchers found that acetylene can be used as the precursor molecule. This new arc-jet method vastly outperforms existing chemical vapor deposition technologies such as low-pressure radiofrequency plasmas and microwave discharges, greatly reducing the cost of producing films to only a dollar per karat. Although the group found a family of molecules that could be used to grow diamond, Cappelli pointed out that "we are just starting to unravel some of the chemistry."

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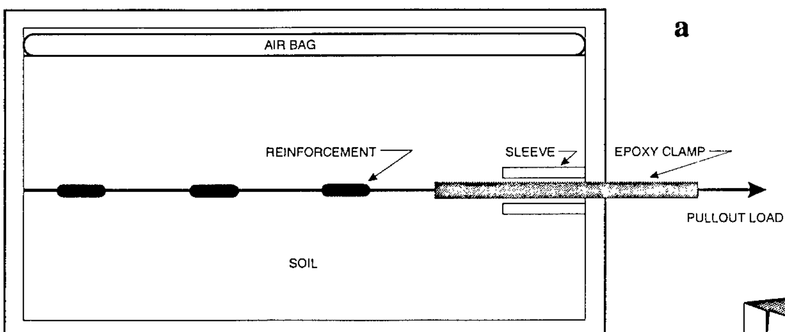
New Protective Structure System Supports Global Reach - Global Power

Capt. Richard Reid, a Wright Laboratory civil engineer, completed a comprehensive test program that demonstrates the feasibility of using reinforced-earth systems for air base protective structures. Capt. Reid's research will lead to a new generation of structures for protecting aircraft, munitions and personnel. These structures will be cheaper and easier to build than current hardened facilities. The new systems will enhance air power projection because reinforced-earth structures are made primarily of indigenous materials, requiring few imported components which can easily be transported by air or sea.



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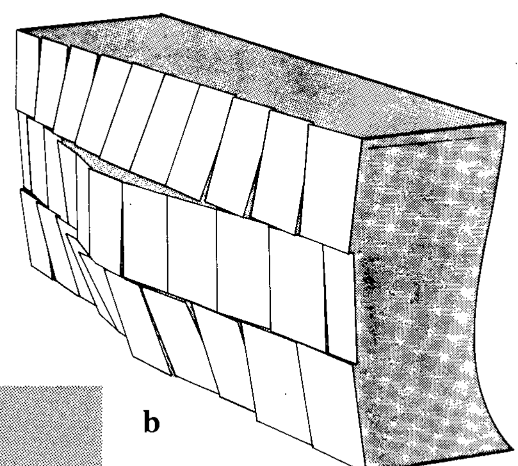

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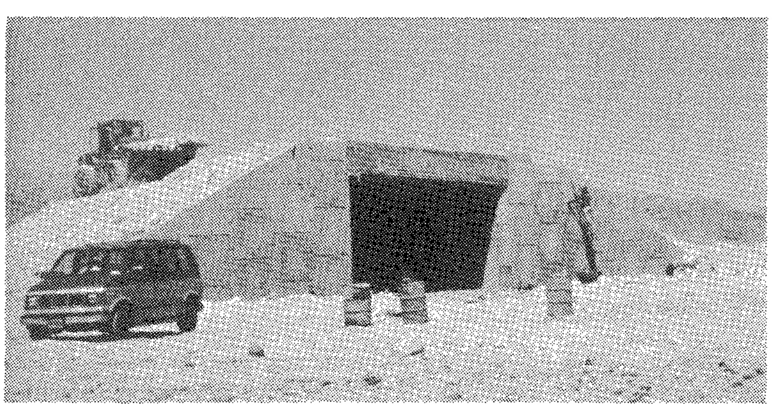
Figure 5. New protective structure system demonstrated in comprehensive test program to support Global Reach-Global Power." Fig 5 depicts (a) a schematic of the laboratory pullout tests which examined the rate-dependence of soil reinforcement interface properties, (b) an artist's conception of a scale-model explosive test at Wright Laboratory's geotechnical centrifuge at Tyndall AFB, and (c) a picture of the bunker used in full-scale testing in Israel.



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The test program included fundamental laboratory, scale-model centrifuge, and full-scale field tests to measure the structures durability in response to conventional weapons explosions. New "constitutive" models for the dynamic response of the composite earth-reinforcement system will be used in numerical codes to develop design guidance for building new protective structures.

This new generation of protective structures could cut construction costs by 20 to 30 percent. Current mobile engineering teams could build the structures using existing equipment sets with little additional training. The structures can also be built in a matter of days versus months or years. Since a reinforced-earth wall is modular, it is also flexible and significantly reduces the deadly spalling (chipping or fracturing from a wall's inner surface) which occurs when today's hardened facilities are struck by conventional weapons.

The characteristic modular pattern of reinforced-earth structures is a common sight along our highways today in the form of embankment retaining walls and bridge abutments. However, there is little information on their response to earthquake or other dynamic motions. Reid's results provide valuable model and full-scale data to help civil engineers understand and predict the behavior of critical infrastructure such as highways and bridges during earthquakes.

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NASA Transitions AFOSR Research to Commercial Requirements

AFOSR sponsored researchers are playing a leading role in a NASA program designed to meet stringent new aircraft engine emission standards. Research performed by the principal investigators is establishing the direction for the application of novel computational analysis methods and laser-based measurements to the production of gas turbine aircraft engines. These new tools are needed to produce the next generation of engines for military and civilian use by the turn of the century.

Both the International Civil Aviation Organization and U.S. authorities plan to impose stringent new requirements on aircraft engine exhaust emissions early in the next century. These requirements are beyond the capability of current engine technology. To fill the acute need for new engine design and development technology, NASA established the Advanced Subsonic Technology (AST) Program to rapidly transition advanced computational methods and experimental techniques. AFOSR sponsored researchers played key roles in the emerging NASA program by organizing and chairing the working sessions of the first AST workshop in August.

NASA called on the AFOSR principal investigators because of their proven "track record" in engine design research. Their research includes work by Dr. Meredith B. Colker of the United Technologies Research Center on the mechanisms of controlling soot formation. Dr. Colker organized an AST working session on chemical kinetics. Research by R.K. Hanson of Stanford University on advanced diagnostics for reacting flows and Warner Dahm of the University of

Michigan on high resolution measuring of mixing and reaction processes in turbulent flows has also been incorporated in the NASA effort. Dr. W.M. Roquemore from Wright Laboratory is responsible for coordination of AST with the DOD Focused Research Initiative. His research in turbulent combustion and fuel sprays has also helped point the way to new analysis methods.

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CFD Research Uncovers Phenomenon Affecting Engine Performance at Supersonic Speeds

In a continuing advanced computational fluid dynamics (CFD) research program at North Carolina State University, researchers have discovered that supersonic and hypersonic (SCRAMJET) airbreathing engines can shutdown during flight as a result of a phenomenon known as "thermal choking." The shutdown or "unstart" condition is a critical problem for supersonic and hypersonic flight vehicles on the drawing boards for the Air Force. Identifying the causes of this phenomenon will have a direct bearing on the design, cost and safety of the next generation of aircraft.

The North Carolina State University Department of Mechanical and Aerospace Engineering is developing advanced CFD methods capable of solving the full three-dimensional, unsteady, viscous flows inside supersonic and hypersonic air-breathing engine inlets in which the unstart

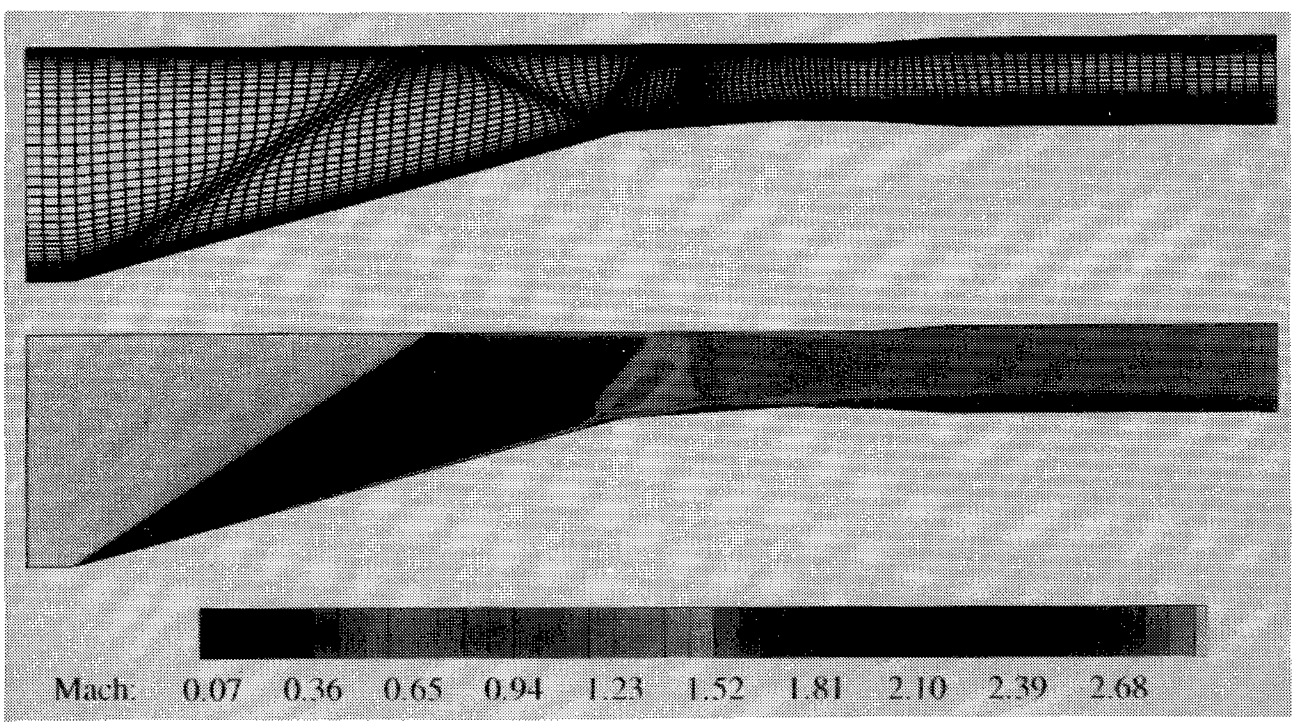

Figure 6. SCRAMJET engine inlet "unstart" due to thermal choking.

condition occurs. The known causes of the unstart condition are increases in operating back pressure and dynamic maneuvering. The researchers have found that increases in free stream temperatures of less than three degrees are sufficient to unstart the engine inlet. The discovery that thermal choking (the entering flow may be too hot) can also cause the unstart condition is especially important for hypersonic SCRAMJETS which operate at conditions where the flow entering the inlet is always very hot. There is a maximum amount of energy the inlet can accept in the incoming flow. When this level is exceeded, the inlet chokes and suddenly shuts down, causing a crash. AFOSR researchers are continuing to investigate this phenomenon to determine the safe operating limits of the inlets.

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New Theoretical Model Provides Insight to Brittle Materials Behavior

University of Pennsylvania scientists have developed a new theoretical model which could lead to the production of Air Force materials with increased ductility and fracture toughness. The model provides insight into the physical mechanisms and properties that control the brittle-to-ductile transition (BDT) of materials. The physical description of this process has eluded materials scientists for decades, but with the new model scientists can predict the brittle-to-ductile transition in materials. Further development of the model could allow materials scientists to select alloying additions which increase the ductility and fracture toughness of Air Force systems such as gas turbine engines and hypersonic vehicle structures.

Drs. David Pope, Vaclev Vitek, and "M." Khantha are researching why certain materials exhibit low fracture toughness in the absence of any apparent physical reason. The brittle-to-ductile transition in materials is most often measured as a critical temperature (T_c) below which a material exhibits brittle fracture. Brittle materials usually lack mobile "dislocations" or a critical stress for dislocation motion that lies above the fracture limit of the material. Despite the critical importance of understanding brittle behavior, the predicted value of T_c in existing theoretical models is typically much higher than that experimentally observed in intrinsically brittle materials.

Pope, Vitek and Khantha devised their analytical model based on a new approach where both dislocation generation and mobility determine the onset of the BDT transition. In their model, the spontaneous (and unstable) emission of dislocations is a necessary condition for BDT, and is the primary process that determines the critical temperature. The calculated values of T_c from the University of Pennsylvania model agree closely with experimental observations for intrinsically brittle materials such as silicon, chromium and tungsten.

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Joint Research Effort Develops New Tools to Study Spacecraft Environment

In a collaborative effort, Professor Daniel Hastings and his MIT research group and scientists from the Phillips Laboratory's Rocket Propulsion Directorate have developed new analysis tools to simulate the environment surrounding spacecraft from low-earth (LEO) to geosynchronous orbit (150 to 44,000 km). AFOSR has supported this extensive research effort since 1987. These tools enable the Air Force to evaluate both the neutral and plasma environments that affect spacecraft operation. They can also be used to design spacecraft with increased capability and longer life on orbit. Hughes Aircraft has adopted these simulation tools to model the local plasma flow environment and assess spacecraft on orbit capability.

An active spacecraft generates its own environment by the release of various effluents. This artificial environment can interfere with the spacecraft's operation in a variety of ways. The main source of effluents is from the operation of the various thrusters which boost and control the satellite. When reacting with the ambient environment, these emissions can cause arcing and electric breakdown which results in the contamination and erosion of sensitive surfaces such as thermal and protective coatings, arrays, windows and sensors. These reactions significantly reduce the efficiency and on-orbit life of space systems and must be thoroughly understood in order to design more effective spacecraft.

The analysis tools developed are based on the fundamental physics that govern the various ionization and transport processes observed in near-earth and geosynchronous orbits. Dr. Hasting's group concentrated its research on modeling rarefied plasma flow with charge exchange, the development of electric fields and surface potentials. The Phillips Laboratory group concentrated primarily on the molecular and ion flow collisions occurring with spacecraft surfaces and direct contamination from plume expansions.

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Directorate of Physics and Electronics

First International Assessment of High-Temperature Electronics Completed

The all-electric aircraft planned for future Air Force use will place stringent demands on the electronic devices and circuits needed for key control and drive systems. Many of these demands can be met by electronics capable of operation at temperatures well in excess of the current military specification upper limit of 125°C. An AFOSR-sponsored committee, led by Professor Hadis Morkoc of the University of Illinois, conducted an international assessment of the status and prospects for high-temperature electronic materials and devices. This is the first assessment covering such new and promising materials as silicon carbide and gallium nitride.

The committee, which also included Professor Robert Davis of North Carolina State University and Dr. Kenichi Nakano of the Air Force's Phillips Laboratory, surveyed U.S. efforts on the subject then visited key Japanese research institutions including university, government and industrial laboratories. Their report compares the state-of-the-art in the various material and device technologies in the U.S. and Japan. One aspect of the report examines commercial or military application "drivers" pushing the various research activities. In general, the report found that Japan is seeking applications of high-temperature electronic materials to areas such as lasers or displays for civilian optoelectronics while much of the U.S. work is driven by civilian and military high-temperature electronic applications.

The report findings were presented to a National Research Council panel conducting a Department of Defense study on the topic. The report is considered a prototype for conducting other foreign technology assessments for Headquarters Air Force Materiel Command. The document is cleared for public release and is available from Dr. Gerald Witt at the number listed below.

In addition to the report, a current list of scientific and technical databases, both domestic and foreign, was prepared as part of the prototype assessment. Another list of companies that perform domestic and foreign technology assessments, both classified and unclassified, was also created. This list includes completed and planned assessment topics. All the lists are available from Dr. Witt or the Air Force Technology Transition Office (DSN 785-5940, (513) 255-5940, or FAX, (513) 476-4580).

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Researchers Demonstrate Silicon-Based Optical Interconnection Technology

Professor Lionel Kimerling and his co-workers at MIT recently made the first demonstration of room temperature light emission from silicon-based devices. Silicon has long been a foundation of microelectronics, but until now it has offered little hope for use in optical applications. Kimerling's breakthrough helps establish a foundation for silicon-based optical interconnection technology, a key in optical computing and communications which will enhance the performance, functionality, and affordability of future Air Force avionics systems.

AFOSR sponsors several basic research programs to create the building blocks of an integrated circuit compatible process technology. The technology will integrate photonics with silicon electronics. By using standard and established process technology and monolithic integration, these programs promote low-cost, high-yield, and high-volume products. The driving force in photonic or optical interconnection research is to find ways to overcome the performance limitations of integrated circuits in the areas of power dissipation, interconnection bandwidth, and interconnection (pinout) density.

Professor Kimerling is exploring silicon light emitters, silicon-based waveguides, and silicon-based detectors to provide integrated circuit compatible process technology. One of the most promising approaches for silicon-based light emitters is the use of the internal "f-shell" transitions of rare earth metals, in this case erbium (Er) which emits at 1.54 micrometers, the wavelength of the minimum attenuation for silica based fiber optics. Professor Kimerling's research group reported room temperature "sharp line" electroluminescence at 1.54 micrometers from an erbium-doped silicon (Si:Er) light emitting diode (LED).

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New Method Improves Compound Semiconductor Fabrication

Dr. James R. Shealy of the Cornell University School of Engineering has developed a new method for the growth of compound semiconductor structures called "flow modulation epitaxy." This method is capable of growing high-purity materials that exhibit higher mobility at low temperatures, more uniform composition, and smoother surfaces than those obtainable from other methods. This simplifies the fabrication of advanced, high-speed opto-electronic structures such as quantum well lasers. This advanced technology will provide the Air Force with ultra-fast communications and computing capability.

Dr. Shealy has also developed a secondary hydride containment system for his process which employs less than one percent of the toxic materials arsine and phospine used in conventional chemical vapor deposition methods. This greatly reduces the risks to the environment and the personal safety of workers who fabricate semiconductors. The university has a patent pending on the secondary hydride containment system and has licensed it to the Commercial Equipment Division of Air Products, Inc.

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New Material Promises Advances in Air Force Optical Systems

Dr. Ian McMichael and his colleagues at the Rockwell International Science Center, Dr. Stephen Rand of the University of Michigan (AFOSR supported both scientists) and M.I.T. materials scientists recently achieved a major advance in the field of nonlinear optics. This group demonstrated the nonlinear optical properties of a material named chromium-doped yttrium aluminate. The material's properties will allow dramatic increases in the sensitivity of detecting weak laser beams. These types of beams can be received by Air Force optical space communications systems or in weakly scattered returns from targets. Laser target designators, which played such a prominent role in the Gulf War, and other "smart" weapons depend on weakly scattered laser light from targets. This light can be very weak in poor weather and combat conditions with heavy concentrations of dust and smoke.

The potential for increasing the sensitivity of detecting weak laser beams, using a process called "nonlinear optical mutual phase conjugation," was suggested a few years ago by Professor Kenneth Gustafson of the University of California at Berkeley while working under an AFOSR grant. Experiments at M.I.T.'s Lincoln Laboratory later confirmed the viability of Gustafson's approach, but they used so-called photorefractive nonlinear materials which required the beams to be of nearly equal intensity for the mutual phase conjugation to occur. This presented a particular problem for the sensitive detection of weak beams where one attempts to receive a very weak beam by "heterodyning" it (mixing two signals of different frequencies) with a strong, locally-generated beam (local oscillator).

Professor Pochi Yeh (an AFOSR grantee) of the University of California at Santa Barbara suggested that this problem could be eliminated and mutual phase conjugation achieved with beams of very different intensity if a material with a large "Kerr" nonlinearity could be found. The yttrium aluminate discovered by McMichael and the other scientists proved to be the ideal material. Their demonstration of a practical nonlinear Kerr medium will make a reality of the conceptual advances in weak laser beam detection.

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Novel Material Produced for Silicon-Based Light Emission

Spire Corporation of Bedford, Massachusetts, an AFOSR small business contractor, has successfully demonstrated a strong, room-temperature 1.54 micrometer emission from erbium (Er) implanted porous silicon (Si). The Spire work, directed by Dr. Fereydon Namavar the principal investigator, holds promise for a new family of optoelectronic devices that will enhance the performance, functionality, and affordability of future Air Force avionics systems.

Although there is considerable knowledge about standard silicon technology, light-emitting silicon has received little attention until recently. The luminescence data obtained by Spire shows that the intensity of infrared emission from Er-doped porous silicon is 100 to 1000 times stronger than that of Er in quartz, a standard material now in use. It is almost at the level of the III-V material used for commercial infrared light-emitting diodes (LEDs). Since no emission was observed from other silicon compounds under similar implantation and annealing conditions, Spire's work indicates high luminescence efficiency originates from erbium being confined in silicon nanostructures less than five nanometers in diameter.

Spire previously fabricated visible (red to orange) LEDs based on porous silicon which are potentially useful as components in display panels or free-space communication. However, their use for optical communication is limited by the attenuation of visible light in fiber optics where the minimal loss occurs in the 1.5 micrometer range. Standard infrared LEDs (InGaAsP) have limited use in optical communications because of their very broad emission spectra and spectral dependence on power and temperature. The luminescence peak from Er in porous silicon on the other hand is narrow and possesses excellent temperature stability.

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New Technique Enhances Nondestructive Evaluation of Aging Aircraft

AFOSR has led an Air Force-wide program to develop new technology for inspection of the aging aircraft fleet for more than two years. Recent research under this program at Vanderbilt University has successfully demonstrated a technique that will improve the capability to detect cracks and corrosion in older aircraft. The improved ability to detect "hidden" defects will help the Air Force fulfill the requirement to extend the service life of its existing fleet, particularly the B-52 bomber and the KC-135 tanker.

Professor John Wikswo led the Vanderbilt team which conducted the research in conjunction with an advisory group of engineers from Oklahoma City and Warner Robins Air Logistics Centers. The team used an array of small superconducting coils connected to an ultrasensitive superconducting quantum interference device (SQUID) magnetometer to detect cracks in aluminum. The team was able to image cracks under rivets in the second layer of aluminum in a mock-up of the

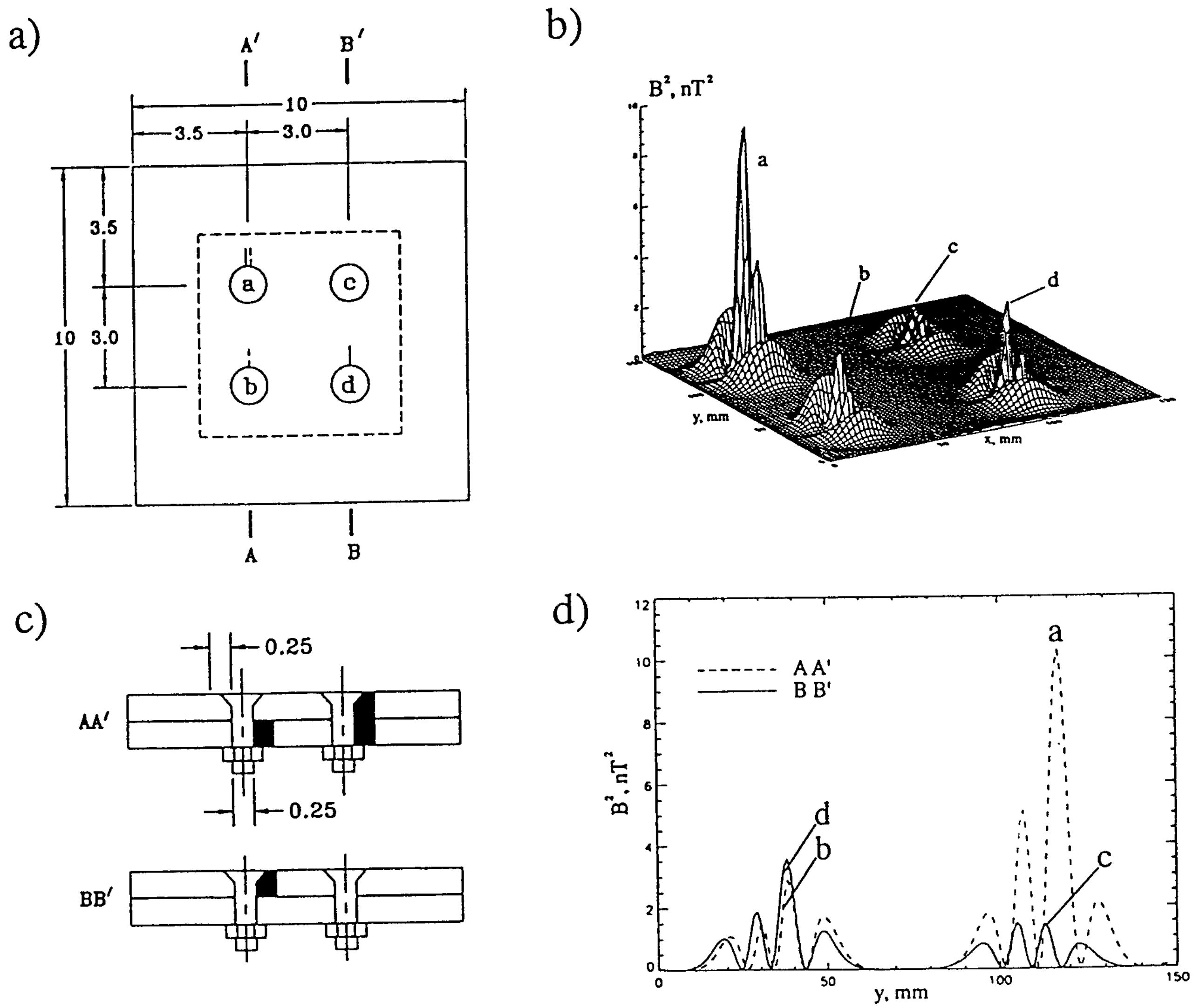

Figure 7. An illustration of a Vanderbilt research team's detection of cracks under the rivets in the second layer of aluminum on a mock up of fuselage conditions found in aging aircraft.

fuselage conditions found in aging aircraft. The researchers machined narrow slots to simulate cracks in a test sample of four rivets. They varied the location of the slots in three of the rivets but made no slot in the fourth one. The research team then analyzed the magnetic field (generated by an eddy current) above the test piece and produced a plot of current density in the vicinity of each rivet. The plot clearly showed the presence or absence of a slot in both the upper and lower layers of aluminum. Eddy current techniques now in use in nondestructive inspection are not capable of this degree of resolution.

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State-of-the-Art Photodetector Developed through Collaborative Research Effort

Researchers at the University of Michigan in collaboration with other AFOSR-funded teams including those at Lockheed-Marietta Laboratory and Purdue University have developed the fastest commercial photoconductor currently available. The speed (seven picoseconds) and spectral range (400 to 900 nanometers) of the device make it ideally suited for a number of military and commercial applications including the characterization of devices for defense millimeter wave radar circuits and the improvement of Air Force optical communications systems.

The photodetector was released for commercial use by the Picometrix Company, a small business spin-off from AFOSR's Research Center of Excellence at the University of Michigan. The device is based on a unique form of the semiconductor gallium arsenide, known as LT GaAs, developed at the MIT Lincoln Laboratory with AFOSR funding. Researchers at Lincoln Laboratory and the

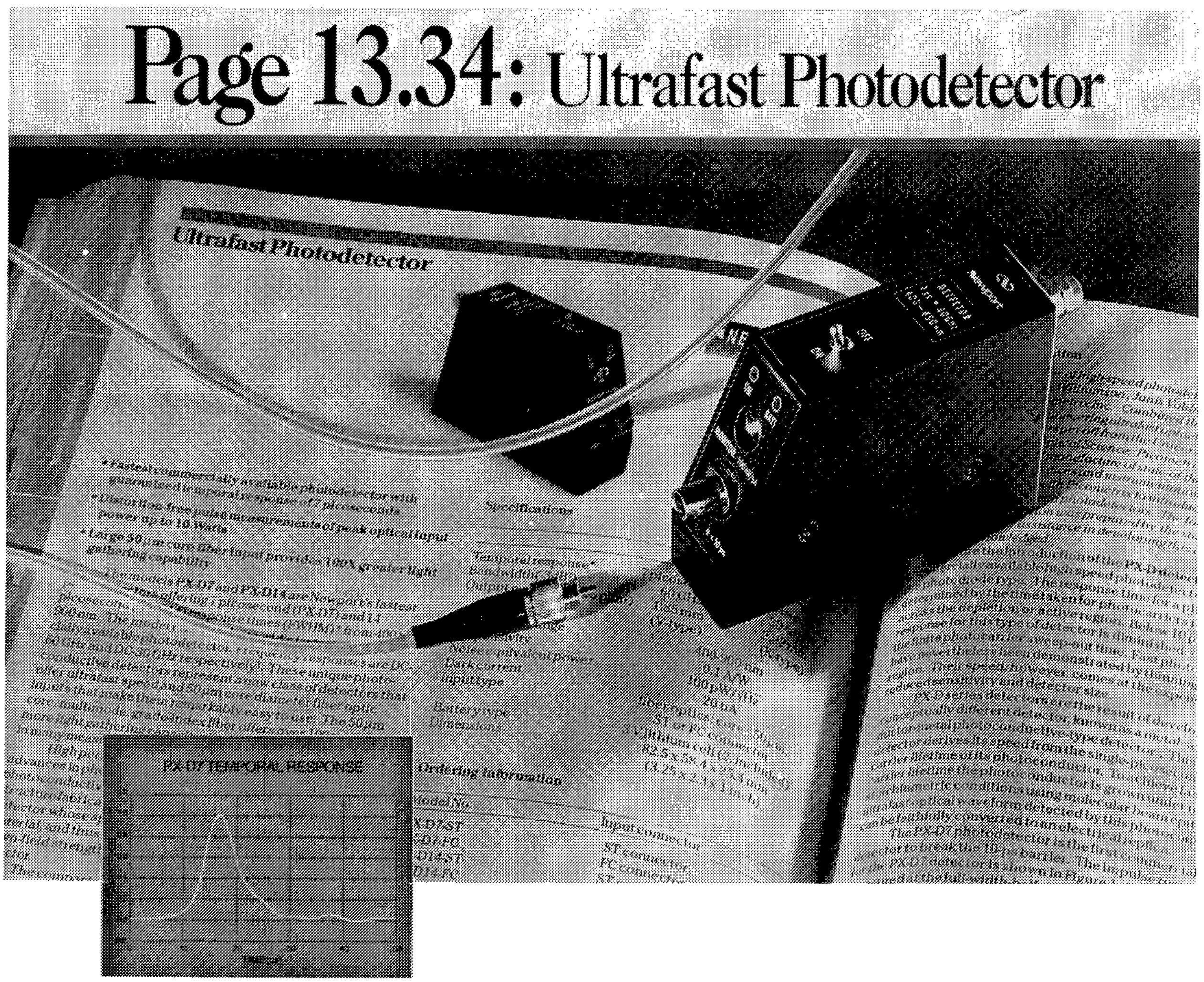

Figure 8. The Ultrafast Photodetector developed by AFOSR researchers and marketed by Newport Corporation.

University of Michigan worked together in developing the optoelectronic applications of LT GaAs. This form of gallium arsenide is grown at very low temperatures, giving it such useful properties as high resistivity, good mobility, high dielectric breakdown strength, and very fast photocarrier recombination, particularly important for the photodetector released by Picometrix.

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Researcher's Theory Leads to New Semiconductor Laser Diode

An AFOSR researcher at Johns Hopkins University has developed a new design concept for semiconductor laser diodes which provides an alternative to the design principle scientists have relied on for the past two decades. Dr. Jacob Khurgin first published his theory for the new design in 1991. Earlier this year, a device group at AT&T Bell laboratories successfully built and demonstrated a working laser diode labeled a "quantum cascade laser" that incorporates all the essential details of Khurgin's design. Using currently available materials, the new lasers are capable of emitting at wavelengths in the infrared near ten microns. These lasers can be used to great advantage in Air Force laser radars and civilian pollution monitoring applications. The new laser design increases the options for selecting emission wavelengths and circumvents the carrier injection and thermalization delays that limit frequency modulation response.

Traditional semiconductor laser design depends on the recombination of an electron and a hole (a site with missing electrons) at the electrically-forward biased junction between two types of semiconductor materials. One material is populated mostly by electrons while the other consists predominantly of holes. Khurgin's design uses only one variety of charge carrier (electrons in present devices) and relies on intersubband electronic transitions in place of conduction band to valence band electronic transitions. He introduced intersubband energy levels into the normal continuum of conduction band levels in bulk semiconductor material by growing alternating ultra-thin layers of two dissimilar semiconductor materials known as "quantum wells." Electrons injected from a power supply into high potential energy states of the modified conduction band "relax" to the lower conduction band edge through a series of intermediate energy levels. Coherent emission, or lasing is induced by "capturing" the photons released in the relaxation cascade in a resonant optical cavity fabricated in the same material.

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New Laser Host Material for Optical Fiber Communications Developed

A research team at the Astralux company under the direction of Professor Jacques Pankove, in collaboration with Spire Corporation and the University of Colorado, has developed the first hot-electron-pumped gallium nitride (GaN) source of 1.54 micrometer erbium radiation. This is an example of erbium-doped semiconductors that have recently attracted worldwide attention as potential sources of 1.54 micrometer emission for optical fiber communications. This material holds great promise for the production of more effective Air Force optical communications systems.

The research team "grew" the epitaxial layers on sapphire and then "co-doped" the material with erbium and oxygen through ion implantation. After implantation, the researchers performed the annealing process at 900°C for one-half to one hour in flowing ammonia. They studied the "cathodoluminescence" as a function of temperature and the 1.54 micrometer emission appeared as efficient at room temperature as at 10° Kelvin. The team's work shows that this material system is very promising for use in electrically-pumped room temperature optical devices that emit in the 1.54 micrometer wavelength.

AFOSR has long been a leader in exploring the group III-V nitride semiconductor material system which includes GaN, aluminum nitride (AlN), and their alloys. Two of the main optoelectronic applications of this system are in the areas of optical computing and space surveillance. The Astralux research will allow expansion into the area of silica-based fiber optics communications. The long term goal of AFOSR-sponsored research in this area is the development of an integrated optoelectronics technology based on the gallium nitride system.

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University Researcher Develops New Class of Lasers

Dr. Dennis Deppe of the University of Texas at Austin has developed a new class of vertical cavity surface emitting lasers (VCSELs) which operate at one-tenth of the current of conventional VCSELs. Small operating currents allow faster modulation and greatly increase the speed and efficiency of fiber optic data transmission. These lasers will provide the Air Force with more efficient and capable high-volume, long distance secure communication networks.

Existing VCSELs require relatively high operating currents because it is difficult to fabricate small diameter current injection contacts. Deppe reduced the current injection contact diameter by selectively converting conducting aluminum arsenide at the contact's outer edge to insulating aluminum oxide while maintaining a small conducting center. This process also reduces the active emitting volume of the laser, limiting the number of emitting modes and bringing the spontaneous emission characteristics under positive control.

Dr. Deppe fabricated VCSELs containing buried layers of aluminum arsenide and exposed them to steam at 500° Celsius. The steam selectively converted the aluminum arsenide to aluminum oxide. Aluminum oxide is favored in laser applications because it is one of the few materials that can be buried beneath gallium arsenide and it refracts light more sharply than gallium arsenide (gallium arsenide is an important material in the construction of surface emitting lasers). Dr. Deppe's process is critical to the formation of the buried layers that define the active cavity of a VCSEL.

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Directorate of Academic and International Affairs

US-Japan Workshop Focuses on Understanding Japanese Management Practices

AFOSR, on behalf of DOD, manages the US-Japan Industry and Technology Management Training (JITMT) Program which funds US universities to establish Japan centers. Ten centers train American scientists, engineers, and managers on Japanese language, culture, and methods of technology management to maximize the competitive and cooperative working relationships with their Japanese counterparts.

The University of Pittsburgh and Carnegie Mellon University organized and hosted a workshop on behalf of all ten JITMT centers at Shin-Yokohama Prince Hotel in Japan on 9 July 1994 for approximately 170 interns. The majority of the US interns were studying in Japanese research and manufacturing facilities, whereas others participated in language training as part of the JITMT Program.

One of the guest speakers in the evening session was Mr. Tsuyoshi Nakai, Director for the Japanese Ministry of International Trade and Industry (MITI). The JITMT Program is gaining a strong support from MITI and US Department of Commerce, that have agreed to expand technical collaborations through more active human resource exchanges. MITI has published a supportive article on JITMT Program in Nikkan Industrial Newspaper that reaches all Japanese industry. This will be very helpful for the JITMT centers to establish relationships with Japanese industry which tends to be rather closed to outsiders.

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Exchange Program Scientist Develops New Technique for Shortened Laser Pulses

While participating in the AFOSR-administered Engineer and Scientist Exchange Program in Stuttgart, Germany, a physicist now working at AFOSR developed a technique for efficiently producing shortened laser pulses. This technique has the potential to increase the output power of a laser more than a thousand times. The short, high-power pulses produced by this technique could greatly improve Air Force laser radars, range finders, designators and other systems that use solid state laser devices.

Dr. Jerome Franck built his laser system using nonlinear optical techniques. He used both phase conjugation and laser-induced plasma switching to compress laser pulses and then return them to the laser oscillator for further amplification, greatly increasing the output power. Initial testing of the system proved difficult because the high peak power of the laser pulses tended to damage optical components. Dr. Franck overcame this problem by placing the optical components away from high "fluence" regions.

Dr. Franck's early experiments showed that this technique could produce a single pulse or a burst of pulses. Using the burst mode under the proper parameters, it would be possible to easily select desired pulse lengths for experimental optical phenomena studies that are dependent on specific pulse lengths. Currently, it is very difficult to probe the reaction of optical phenomena to varied pulse lengths. Pulse-length dependent phenomenological studies now require a separate laser configuration for each of the desired pulse lengths under study, a procedure that is fairly complicated and very expensive. Other advantages of Franck's technique are small packaging, simplicity of design, and insensitivity to optical misalignment.

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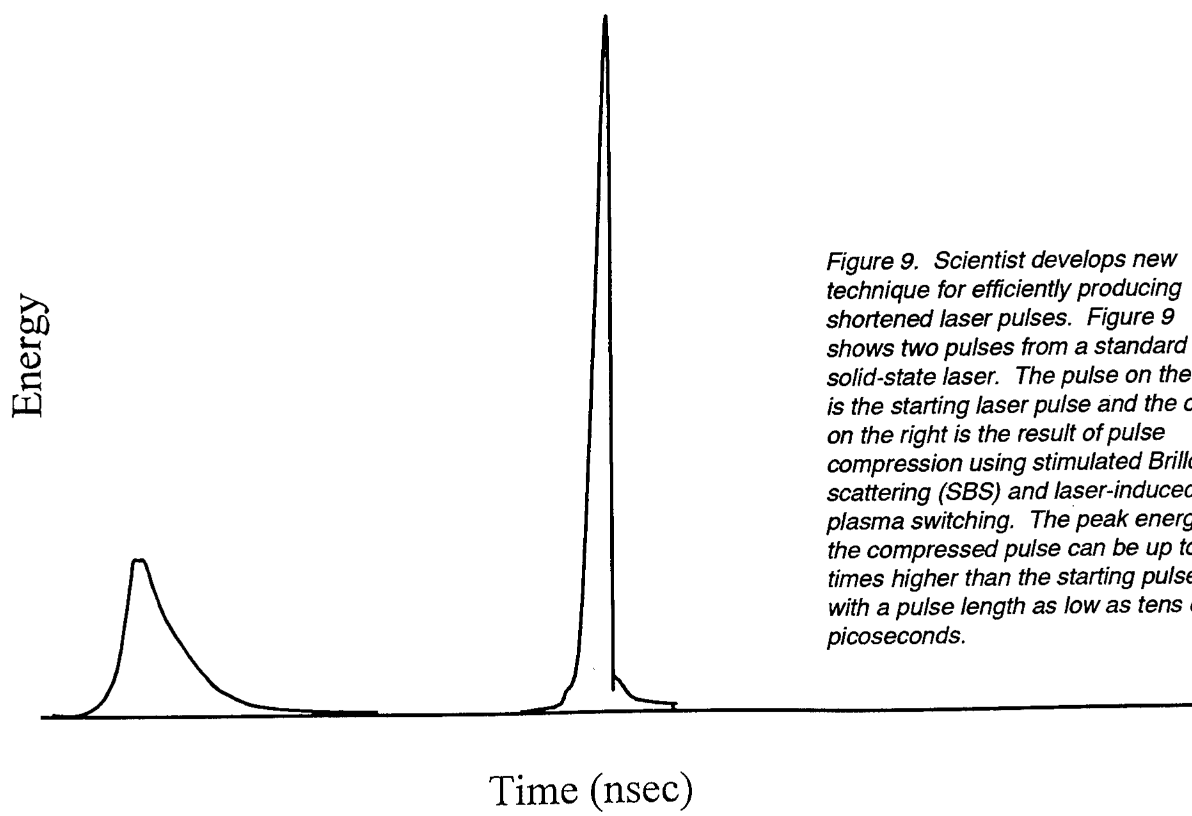

Figure 9. Scientist develops new technique for efficiently producing shortened laser pulses. Figure 9 shows two pulses from a standard solid-state laser. The pulse on the left is the starting laser pulse and the one on the right is the result of pulse compression using stimulated Brillouin scattering (SBS) and laser-induced plasma switching. The peak energy of the compressed pulse can be up to six times higher than the starting pulse, with a pulse length as low as tens of picoseconds.

Directorate of Chemistry and Life Sciences

Research Chemists Discover Environmentally Friendly Method to Produce Semiconductors

Duke University chemists Richard Wells and Louis Coury Jr. have devised new and safer ways to synthesize gallium arsenide and other important "III-V" semiconductors. In the process, they also found a way to produce semiconductor materials of infinitesimal "quantum dot" dimensions. Both discoveries are important for the development of electronic and opto-electronic devices for future Air Force avionics, computation, and communications systems. Quantum dots consist of only a few thousand or less atoms. Electrons trapped in such tiny spaces behave in ways that make the dots ideal as the basis for supersmall, exceptionally powerful electronic and electro-optic devices.

The III-V semiconductors—named for their constituent atoms' group numbers on the periodic table of elements—have several advantages over silicon-based electronics materials. Unlike silicon, they can be made into devices that operate at microwave frequencies. They are also more radiation-tolerant than silicon. The III-V's can also easily convert electricity into light for emission by diodes or lasers, the technology basis of futuristic electro-optic devices.

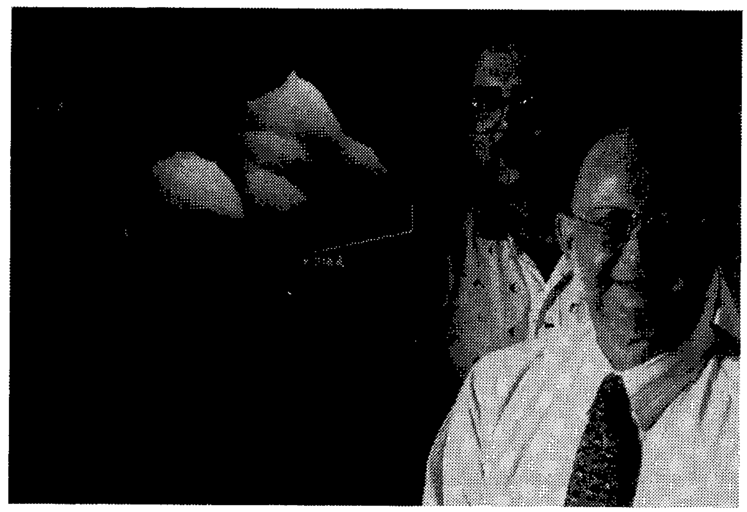

Figure 10. Duke chemists Richard Wells, front, and Louis Coury Jr., devised newer and safer ways to synthesize gallium arsenide and other semiconductors. In the process they discovered ways to produce crystals

Unfortunately, unlike silicon, the synthesis of III-Vs requires high temperatures and chemicals that are toxic or which spontaneously ignite when exposed to air. The Duke University team's overall objective is to find new ways to form the chemical bond that links Group III elements, such as gallium, with Group V elements including arsenic. The traditional approach to producing gallium arsenide combines trimethyl gallium—which spontaneously ignites in air—and toxic arsine gas in a potentially explosive atmosphere of hydrogen at a temperature of 700°C. The Duke team's approach is to use a "metathesis" reaction of gallium trichloride with tris (trimethylsilyl) arsine to produce the III-V gallium arsenide. This reaction occurs at 75°C, does not need hydrogen, and eliminates the use of the toxic gas arsine.

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Microorganism Isolated That Biodegrades Hazardous Wastes

Dr. Ronald Crawford and his research team from the University of Idaho have recently isolated an anaerobic strain of bacteria that can use TNT, the explosive nitro compound, as a sole source of food. In the process, the bacterium degrades TNT into nontoxic intermediates which are, in turn, converted by naturally occurring soil microbes to the fundamental products of carbon dioxide and water. The highly-energetic propellant compounds RDX and HMX used by the military are also degraded by this newly identified bacterial strain. This bacterium will enable the development of environmentally safe and inexpensive processes for cleaning up contaminated soils around Air Force bases and disposing of outdated and unused stocks of TNT, RDX and HMX.

Nitro compounds are generally difficult to biodegrade without the concomitant accumulation of highly toxic intermediate products. In the case of the nitro aromatic TNT, gene-damaging intermediates that include aryl amines and phenols are frequently produced. Dr. Crawford's approach was first to isolate and characterize the microorganisms capable of degrading nitro compounds into non-toxic products. Once characterized, he studied the underlying biochemical mechanisms involved in biodegradation to learn how to manipulate and enhance the biodegradative potential of these microorganisms. After more than two years of continuous culturing of microorganisms in media containing varying concentrations of TNT, RDX and HMX, Dr. Crawford identified the bacterial strain of Clostridium that can "anaerobically" degrade TNT to simple straight-chain organic acids without the accumulation of toxic intermediates. He is now directing research efforts to describe the biochemical pathways and enzyme kinetics involved in the degradative process and elucidate the molecular mechanisms of pathway regulation.

The J.R. Simplot Company of Pocatello, Idaho has incorporated the Clostridium bacteria into a bioreactor system. The system is being tested by the U.S. Environmental Protection Agency's Superfund Innovative Technology Evaluation program for its potential to remediate soil contaminated with TNT. Interim test results indicated success.

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Photorefractivity Improvement Holds Promise for Low Cost Materials

Professor Nasser Peyghambarian and his co-workers at The University of Arizona have reported the highest diffraction efficiency (35%) to date of a photorefractive polymer. Professor Peyghambarian's work represents a significant advancement in the field of organic photorefractivity and has great potential for speeding up the development of low cost materials, devices and systems for many Air Force applications ranging from optical storage to target recognition.

Photorefractive material allows one to control a light beam, sometimes known as the read or probe beam, by another laser beam known as the write or pump beam. This effect can be used to amplify optical signals in data processing, much the way a semiconductor transistor does in electronics. Photorefractive material can also be used to store and display holograms (3-D images) in optical storage and target recognition applications analogous to photographic films and cathode ray tubes (CRTs) in handling 2-D images. It can be used to steer the direction of a light beam when controlling the routing of optical signals in a communication network or in optically tracking a target with laser radar.

The field of organic photorefractive materials is relatively young. Prior to 1990, all known photorefractive materials were inorganic crystals or semiconductors. The first organic photorefractive materials reported in 1990 only had a diffraction efficiency in the order of 10^{-3} of a percent. Using a different chemical composition to combine the electro-optical properties and photo-induced conductivity, the two properties necessary to generate the photorefractive effect, Professor Peyghambarian was able to enhance the photorefractivity up to 35 percent. He accomplished this improvement using a 125 micron film. To get comparable diffraction from an inorganic material would have required a film thickness in the millimeter range. The photorefractivity of this film was so strong that it was possible to write and read holograms on the material with a low-power laser diode, reportedly a first-ever achievement. This feature will be important in developing low cost systems for many applications requiring the function of photorefractivity.

Dr. Charles Y-C Lee
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Integrated Circuit Model of Human Hearing to Improve Speech Discrimination

Dr. Shihab Shamma of the University of Maryland has developed a model of human auditory encoding. The new model shows promise for duplicating human abilities to hear specific sounds in background noise and to extract phonemes, the fundamental elements of speech. The model is now available as an integrated circuit for use in real-time applications of acoustic signal processing. The Air Force can use this circuit for speech recognition systems that will work in noisy, cluttered environments. The Armstrong Laboratory plans to study the utility of the circuit as a front-end signal processor for such systems.

Humans are able to perform certain hearing "tricks" such as listening to one conversation in a noisy, crowded room or precisely locating the source of a moving sound. However, scientists working on systems for automatic speech recognition have found it very difficult to duplicate these human abilities. Use of speech recognition systems has been limited to quiet environments, small vocabularies and simple sentence structures. Scientists studying acoustic signal processing in humans know that people rely on very fast sophisticated guesses about what will be heard next and the techniques used for encoding sounds in the first place. Dr. Shamma's model greatly facilitates the study of this process.

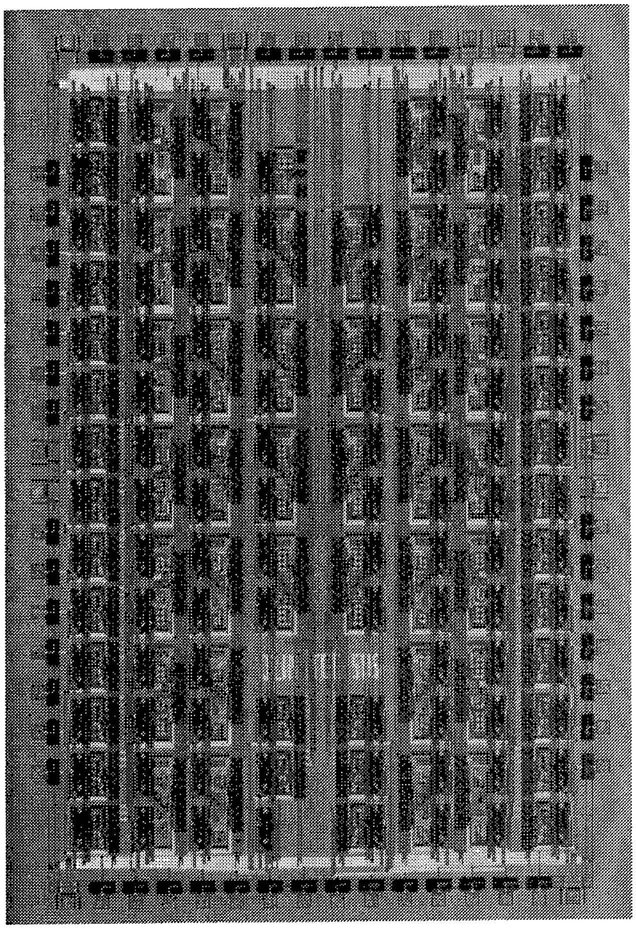

Figure 11. Figure 11 depicts the layout for an integrated circuit, no larger than a pea in cross-section, that simulates acoustic signal processing in the human ear. Computer chips based on this circuit can improve hearing aids and other devices for improved speech discrimination.

Dr. Shamma's original computer model was necessarily complex, describing by equation the filtering and nonlinear interactions found during experiments. It was slow to run and restricted to laboratory use because most speech recognition systems must work fast enough to be described in real-time. However, a graduate student working in Dr. Shamma's laboratory succeeded in transforming the model into a single integrated circuit, or chip. As a single chip, the model can be considered for use in hearing aids or microphones where human-like acoustic signal processing can be used effectively. Scientists will also benefit from the integrated circuit which works much faster than the earlier software version. One significant challenge overcome in designing the model to fit on a single chip involved a technique of constructing "capacitances" large enough in value to filter the relatively low frequencies of speech sounds yet small enough to fit an array on a single chip.

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Molecular Chemistry Breakthrough to Improve Optical Materials

Dr. Seth Marder of the Beckman Institute at the California Institute of Technology has made a discovery in molecular chemistry that will hasten the development of nonlinear optical materials for Air Force applications such as phased array radar control, high density interconnects for advanced electronics, and lidar (laser infrared radar). Dr. Marder discovered and demonstrated the importance of the bond alternation parameter for controlling molecular "hyperpolarizability," the molecular origin of optical nonlinearity in conjugated systems.

The importance of nonlinear optical materials to photonic applications can be compared to that of semiconductors to electronics. They can be used to modulate the magnitude and phase of laser light, enabling high speed and large volume communications and signal processing with light waves. The bond alternation parameter is a measure of the difference in bond length between the alternating double bonds and single bonds in a conjugated molecule. Using computer calculation, Dr. Marder was able to show that the first and second order hyperpolarizabilities should show "maxima and minima," with appropriate sign changes as a function of this bond alternation parameter. By synthesizing a series of these molecules, he was able to experimentally reproduce the theoretical predictions by measuring the hyperpolarizabilities of the molecules in solution.

Marder's discovery adds an important level of understanding to the design of molecules with nonlinear optical properties. Prior to his work, the understanding was limited to quantum mechanical formalism which is difficult to translate into molecular structure requirements. With this new framework, it is easier for chemists to design molecules with large hyperpolarizability and with the correct signs based on molecular structures instead of abstract wave equations.

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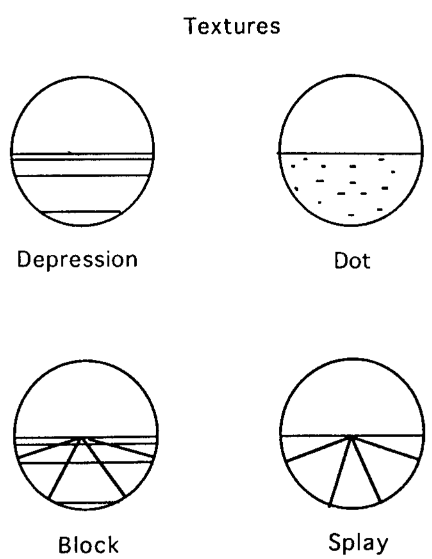
New Visual Cue Technique Will Improve Helicopter Flight Safety

A research team at Wright State university, led by Dr. John Flach, has demonstrated the visual sources of information in helicopter operations (splay, depression, grid and dots) that are used to transition from low-level flight to a hover. The team's research has significantly increased knowledge of the visual information sources and resolved several inconsistencies from previous studies. The results will aid helicopter and V/STOL aircraft pilots to safely transition to and from the hover environment.



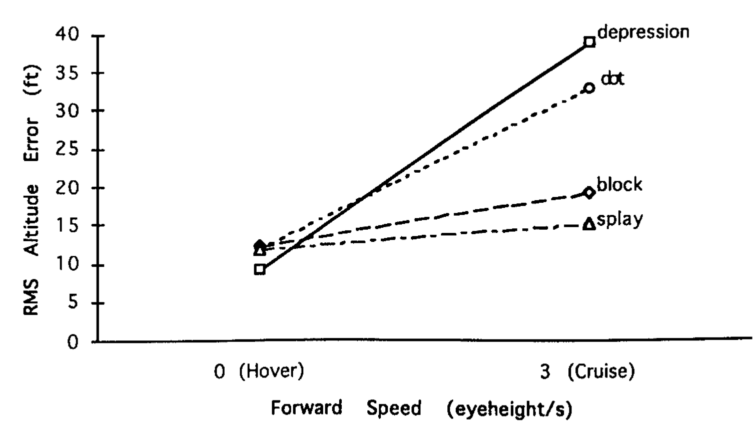


Figure 12. The importance that different visual cues have on the precise regulation of altitude depends on the type of vehicle motion (hover or cruise) as shown in the figure above. For hover, the most precise regulation of altitude is obtained when cues show position of ground texture relative to the horizon (as isolated in depression texture). Conversely, the angular position of texture relative to the line of motion (as isolated in splay texture) is clearly superior at cruising speeds and is the least affected by ground speed variations.

One major challenge in helicopter maneuver research is determining the most salient visual cues in transitioning to and maintaining the important hover portion of flight operations. Previous research produced conflicting results on the visual information used for altitude control of a hovering helicopter. Altitude control during a hover maneuver is much different than in low altitude flight with fixed-wing aircraft. Depression angle is the most critical source of information in helicopter hovering operations. Flach and his colleagues demonstrated that the forward flow rate (equivalent to fixed-wing ground speed) in helicopters is a critical intervening variable. The depression angle is a critical source of information at low forward rates (hover), but as flow rate (or ground speed) increases it becomes difficult to use it to judge altitude change.

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University of California Team Develops Drug to Enhance Memory

A University of California (Irvine) research team has developed the first drug that appears to improve working memory. This could greatly benefit the Air Force whose shrinking force level faces an increasingly complex world in which to conduct its mission. Any improvement in the working memory of operational, planning, maintenance and other personnel would be of tremendous value in handling the voluminous amounts of information they face.

Dr. Gary Lynch's research team developed the drug during their research on the kinds of chemical and structural changes in the nervous system thought to underlie the learning process. The team was investigating changes in the hippocampus, an area of the brain known to be involved in learning and memory. As part of the research, they designed a special chemical to increase the mean open time of specialized receptor channels called AMPA receptors. These receptors act as gates to transport the excitatory neurotransmitter glutamate across the cell membrane and set in motion a complex set of intercellular events capable of exerting the lasting influences which underlie memory.

Dr. Lynch's designer chemical significantly decreases the time for normal, healthy rats to learn a variety of tasks. The neurochemistry of learning in rats is considered very similar to human neurochemistry. The drug's effects should be similar in humans. The drug is designed to cross the blood-brain barrier intact and can be administered orally. Cortex Pharmaceuticals, Inc., plans to test the toxicology of the drug in preparation for obtaining FDA approval to test its effects on humans.

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Researchers Develop New, Non-Invasive Medical Imaging Technology

An MIT researcher and his colleagues from several other research institutions recently developed a new, non-invasive medical imaging technology called optical coherence tomography (OCT). AFOSR, the National Institutes of Health (NIH) and the Office of Naval Research (ONR) jointly sponsored this multidisciplinary research effort. The new imaging technology developed by Dr. James Fujimoto and researchers from the MIT Lincoln Laboratory, the New England Eye Center, and the Massachusetts General Hospital can perform high resolution (less than 20 microns) cross-sectional images of the human retina in real-time. The Air Force currently uses OCT to develop an understanding of the interactions between lasers and human eye tissue and to establish ocular safety standards for ultrashort (sub-nanosecond) laser pulses. This technology has many other potential biomedical applications including the diagnosis of retinal and ophthalmic diseases, the characterization of coronary artery diseases, and the performance of novel types of endoscopic optical biopsies.

OCT is based on the principle of low coherence interferometry. The OCT scanner splits infrared light into two beams. One beam travels to the object to be measured while the other is directed to a movable reference mirror. The reflected light from each beam is then recombined and interference is produced when the distances of the light reflected from the object and the mirror are equal. As the beam scans the object, two-dimensional images are created by mapping the interference patterns with the help of image processing software. Since each repeated movement of the reference mirror will image the object at a different depth, sequential images can be created and then computationally combined to produce a three-dimensional (tomographic) representation.

OCT offers an in-depth, detailed view of the retinal microstruture prior to laser damage and also displays the extent of damage over time. Before the development of OCT, this process was visible only with radical eye removal procedures. OCT is proving very useful in establishing a national and Air Force health safety standard for personnel working with sub-nanosecond laser pulses.

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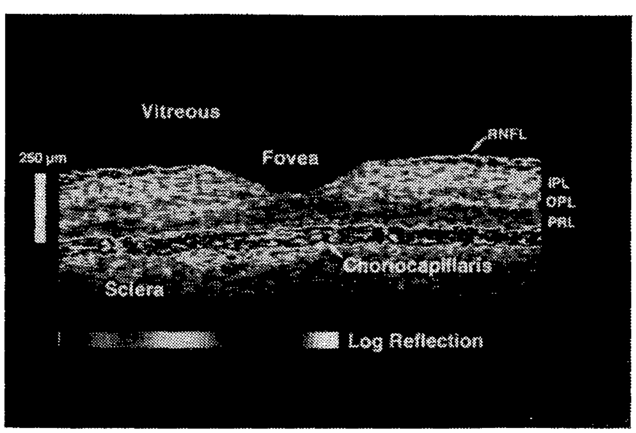

Figure 13. Figure 13 is an "in vivo" optical coherence tomography (OCT) image of the retina in the left eye of a human subject. OCT images like this, produced by reflections from the internal structures of the eye, can make it possible to pinpoint the earliest signs of ocular diseases or laser injury.

Conversion Process Reclaims Chemical Waste for Reuse

A research group at the General Electric Corporate Research and Development Center, Schenectady, N.Y., has successfully converted hazardous waste material generated in the production of fiber-reinforced structural composites needed for the F-117 stealth fighter for reuse. Conversion of the material to chemical building blocks allows reuse for structural composites or for electronic applications. The Air Force recovers some of the initial material cost and eliminates the expense of hazardous waste disposal costs.

The fiber-reinforced structural composites used in the F-117 are based on a new, high temperature composite material known as Air Force Resin 700B which solves the problem of recurring heat damage on the aircraft's fuselage trailing edges. The resin increases the temperature capability of the organic matrix composite by 150°F, improving the aircraft's performance while maintaining its low-observable profile. The resin was developed under a joint Wright Laboratory-Sacramento Air Logistics Center (ALC) program which recently received the General Thomas Ferguson Award given annually for excellence in technology transition. In a close collaborative effort, Sacramento ALC and the General Electric aircraft engine facility in Evendale, Ohio, are supplying resin samples to the GE research group.

The resin is very expensive ($1,170 per quart) due to one of its monomer chemical constituents known as "6-F dianhydride" which sells for $375 a pound and makes up 75% of the dry weight of

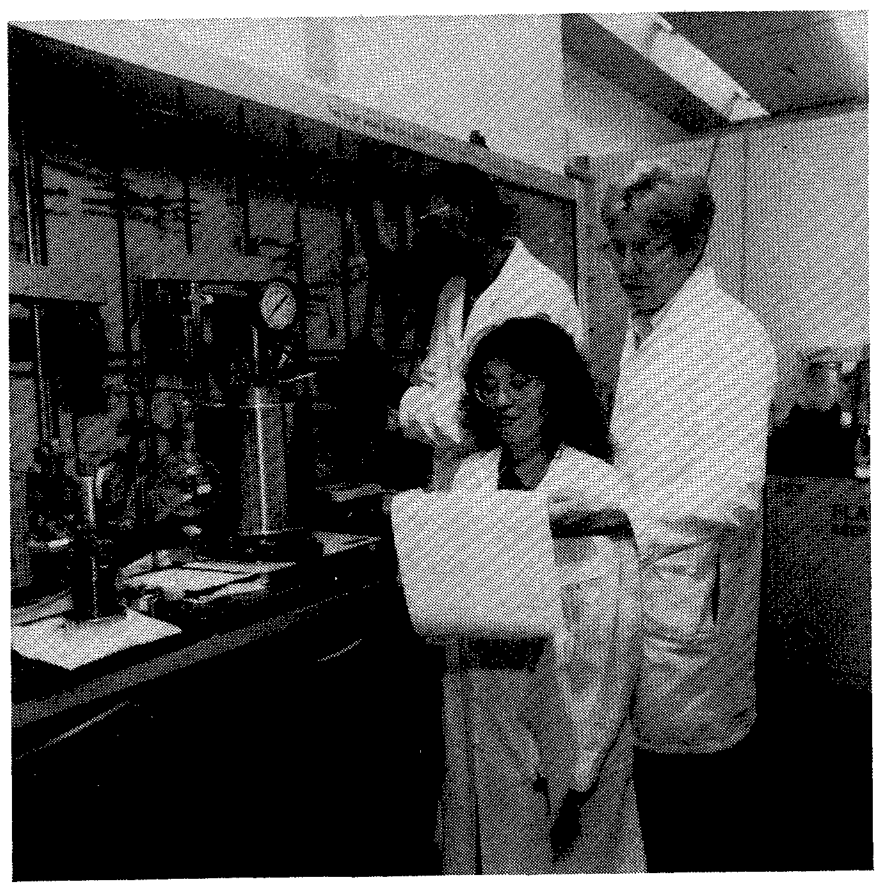

Figure 14. General Electric researchers have successfully converted hazardous waste material for reuse in structural composites or electronic applications. Andrew Caruso and Julia Lee evaluate liquid chromatography analysis output, while Andre Johnson adjusts the autoclave reactor in preparation for a depolymerization run to reduce hazardous material to its basic "building blocks."

the material. The new process developed by the GE group allows the recovery of 6-F dianhydride by treating the waste material obtained during production of the structural composites with an amine catalyst at high temperature and pressure. This results in the "unzipping" of the resin polymer to its monomeric constituents including 6-F dianhydride.

The researchers believe this novel approach to recovering value from waste can be extended to other polymeric composites. It also represents a more cost-effective and environmentally benign way of disposing of waste than destructive methods such as burning or biodegradation This chemical conversion process also makes Air Force Resin 700B more attractive for commercial use. A larger volume of civilian applications would further drive down costs. Potential commercial applications include structural composites for turbine engines and piping for oil fields and geothermal wells. The General Electric research team, headed by Dr. Andrew Caruso, is "optimizing" the chemical conversion process for maximum recovery of 6-F dianhydride.

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Knowledge of Fundamental Friction Principles to Improve Aerospace Lubricants

Using an atomic force microscope, a Harvard University research team has demonstrated the ability to measure the fundamental forces at work in solid lubricants. By successfully manipulating nanometer size clusters of molybdenum trioxide (MoO_3), the oxidation product of the widely used solid lubricant molybdenum disulfide (MoS_2), the team was able to gain fundamental information about the frictional forces on the lubricant's surface. This knowledge can be used to determine ways to prevent the breakdown of MoS_2 and design a family of longer lasting, high-temperature lubricants required for high-performance Air Force systems.

The atomic force microscope employs a cantilever probe with a tip consisting of only a few atoms. The application of a small amount of pressure enables the tip to scan a surface, producing a microscopic image. When a large force is applied, clusters can be moved about the surface. In one set of experiments, ionizing energy from the tip "cleaved" a small piece of MoO_3 from its parent cluster. The research team subsequently pushed this piece across the MoS_2 surface, generating data on the amount of frictional force adjacent atoms on the surface possess. In another set of experiments, the researchers were able to spread apart the MoO_3 at a 60 angle which was indicative of the surface energy "minima" of the MoS_2 hexagonal lattice. This work represents a major advance in tribology since it allows scientists to accurately determine the individual forces between atoms. The ability to determine these forces will greatly aid in the a priori design of new lubricants and lubrication systems.

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Phillips Laboratory Demonstrates Improved Rocket Fuel Additive

High Energy Density Materials researchers at the Phillips Laboratory have successfully demonstrated a new energetic hydrocarbon additive for liquid rocket fuel (RP-1) in an engine firing at Edwards Air Force Base. This AFOSR Star Team is led by Dr. Stephen Rodgers. Fuel containing the new additive will undergo larger scale testing to evaluate its ability to completely replace the liquid fuel currently used in Atlas and Delta rockets without having to modify existing hardware. If the tests are successful, the new fuel mixture should enable the launch of significantly larger payloads without increasing the launch costs.

The extra energy of the additive is derived from bond-strain energy built into the hydrocarbon molecules. By adding these high positive enthalpy molecules to conventional fuel, scientists can increase combustion energy which improves performance. The initial additive formulation examined by the Phillips researchers provided a five-second specific impulse (Isp) improvement over the currently used liquid hydrocarbon rocket fuel. Each second the Isp is increased equates to roughly 100 pounds of additional payload capability for the Atlas and Delta launch systems. By using the new fuel additive, oversized payloads can be kept on existing launch platforms saving millions of dollars per launch.

Scientists in the Phillips Laboratory have also developed several new synthetic "routes" for producing compounds, providing Isp increases of up to 20 seconds. These higher performing compounds are currently being examined at Phillips for engineering and economic feasibility. Phillips Laboratory is also developing "heteroatom-strained" systems (carbon atoms are replaced with an atom of another element such as nitrogen) which promise a much higher payoff than the pure hydrocarbon systems.

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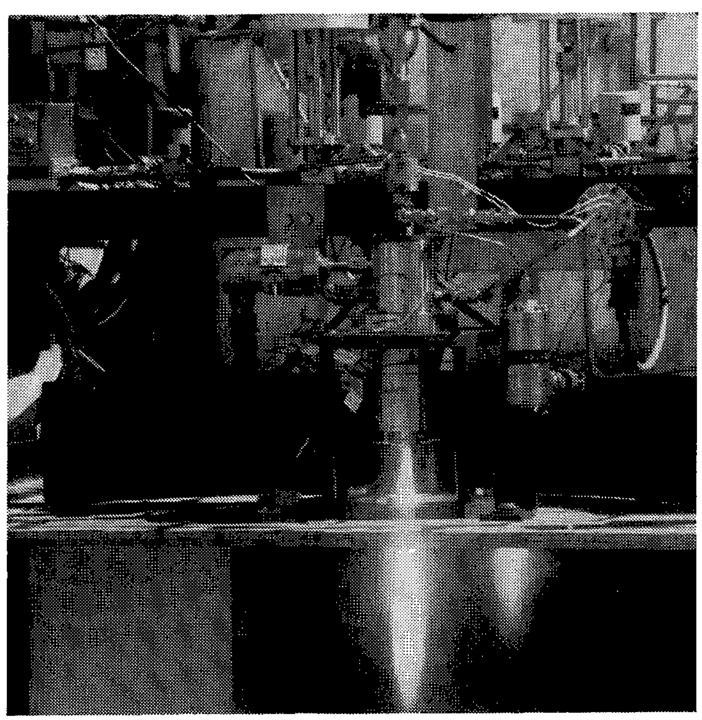

Figure 15. Phillips Laboratory researchers successfully demonstrated a new hydrocarbon additive for liquid rocket fuel which could enable the launch of larger payloads without increasing costs. The additive is shown being tested in the laboratory's rocket thruster.

Directorate of Mathematics and Geosciences

Seismic Research Improves Air Force Capability for Nuclear Monitoring

A geophysical and seismological investigation conducted by an international team of research scientists has led to a major improvement in the seismic models required to conduct the Air Force's nuclear monitoring mission.

The international team of scientists included Dr. John Cipar of the Phillips Laboratory's Earth Science Division, Dr. Keith Priestly of the University of Cambridge (England), and Drs. Anatoly Egorkin and Nina Pavlenkova from two Moscow organizations, the Center for Regional Geophysical and Geoecological Research and the Russian Academy of Science, respectively.

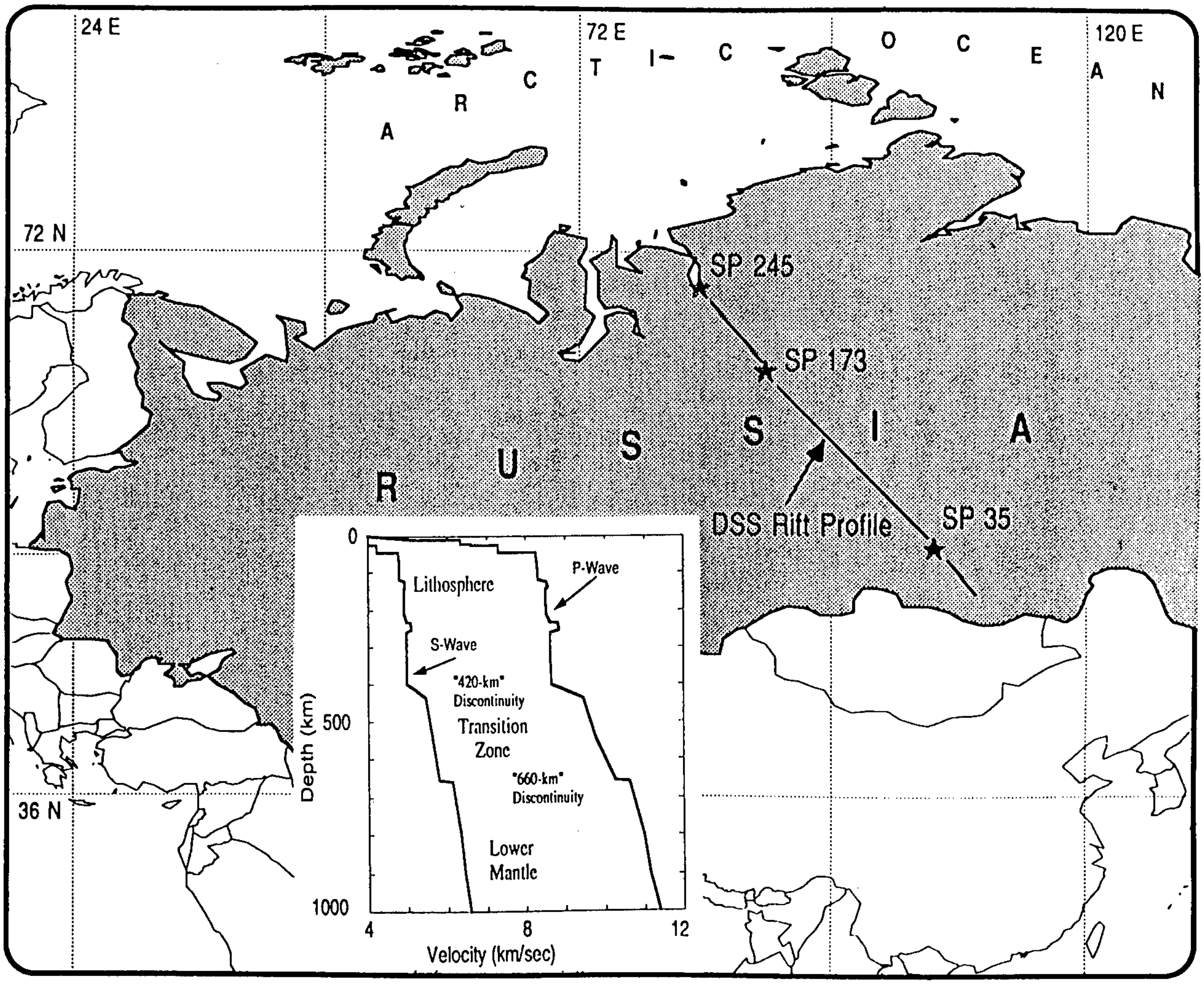

Figure 16. The Seismic model for Central Siberia showing the 2400 kilometer long profile (starred line) from the Yamal Peninsula to Lake Baikal. The insert illustrates the seismic wave velocity structure for Central Siberia to a depth of 1000 kilometers.

The team studied the earth's crust and upper mantle underlying the Siberian craton (structural platform). They performed the research along a 2400 kilometer-long profile extending from the Yamal Peninsula to Lake Baikal. Nuclear and chemical explosions along the profile provided deep seismic sounding measurements which allowed detailed crustal and upper mantle observations. The geophysical variations discovered at the crust-mantle interface and discontinuities evidenced in the deeper mantle in this region result in abrupt increases in seismic wave velocities. Improved understanding of such regional velocity variations significantly improves the Air Force's ability to accurately locate and estimate the yield of seismic events such as underground explosions.

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Weather Forecasting Improved by Incorporating Satellite Water Vapor Data

Mr. Don Chisholm and his research team at the Phillips Laboratory Geophysics Directorate have shown that incorporating satellite water vapor data into weather prediction models improves forecast accuracy. The Phillips Laboratory is using their research results to better predict regions of potential thunderstorm activity. Application of this research will allow Air Force forecasters to provide theater battlefield planners with more timely, accurate forecasts of mission-limiting weather conditions.

Working with many other university and government scientists, the Phillips Laboratory group collected data during the Convective and Precipitation/Electrification (CaPE) experiment over central Florida. The group used geostationary satellites to obtain vertical profiles of water vapor, an important factor in developing thunderstorms, and added this data to the weather model database. A comparison of the forecasts from the satellite enhanced model with those based on conventional weather data showed the former was much more accurate. In one case study, the satellite enhanced model accurately forecasted two regions of potential thunderstorm activity while the conventional data model failed to predict either region. The group's work moves the Air Force a step closer to its goal of accurate, theater-level weather forecasts.

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Novel Optical-Fiber Amplifier Offers Improved Communications

Dr. William Kath, professor of applied mathematics at Northwestern University, and his colleagues have developed phase-sensitive amplifiers (PSAs) that promise improved point-to-point optical communication irrespective whether these points are at bases, within aircraft, or inside optical computers.

The PSAs work at any wavelength and do not suffer from the mismatch between erbium-doped fiber amplifiers (which operate at 1.5µm wave length) and the fused-silica fibers (which transmit a 1.3µm wavelength signal most efficiently) currently used. The phase-sensitive parametric amplifiers work to produce an output pulse that is uniform in phase and thus eliminates the phase sweep induced by dispersion during propagation. The phase matching achieved by the group's device insures that signals can be transmitted further and with less error (even spontaneous emission noise is eliminated) than previously thought possible.

This fundamental advance is attracting considerable attention in the optics community. It was cited in the "Optics in 1993" issue of Optics and Photonics News as one of the "principal advances in the field of optics over the past year."

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Solar Research Discovery Helps Protect Space Systems

Researchers in the Geophysics Directorate of the Phillips Laboratory identified three components of relativistic solar particles during a solar flare. The three components discovered by the scientists were solar neutrons, protons from the decay of solar neutrons and solar protons. These components were all in the extremely high giga-electron volt (GeV) energy range (one GeV equals 0.0016 ergs). Knowledge of the existence of these components will aid in the prediction of solar particle events and help protect Air Force space assets.

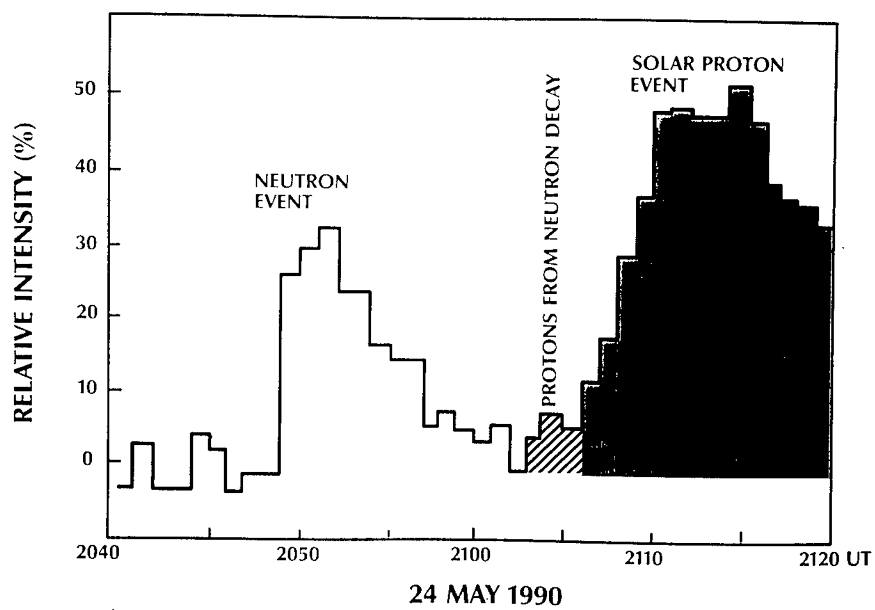

Figure 17. The identification of three components of solar flares by the Phillip's Laboratory's Geophysics Directorate will help predict solar particle events and protect Air Force space assets. Figure 17 charts the relative intensity of the three components of solar particles during a solar flare.

This observation was the largest direct measurement of solar neutrons near the Earth reported to date and the first reported measurement of all three components on the surface of the Earth. The Air Force needs a model to predict the arrival of solar protons at the Earth since solar particles can seriously degrade space systems. High-energy particles can penetrate into the innermost sections of spacecraft components. If these particles interact with a nucleus, they create a "nuclear star" which can cause temporary or permanent damage to sensitive semiconductor components. There is no effective way to shield spacecraft components from energies in the GeV range.

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Advances in Digital Signal Processing to Improve Combat Communications

An MIT research team led by Professor Alan V. Oppenheim recently achieved a critical breakthrough in the noise cancellation technology for combat communications systems. For decades, the technique of active noise cancellation (ANC) in these systems has seemed imminent. Thanks to the advances made by Oppenheim's group in digital signal processing (DSP) and the availability of compact, fast DSP hardware, the ANC technique is now nearly ready for incorporation into the headphones used by Army tank crews and Air Force pilots. Installation of this improvement will significantly improve the clarity of Army and Air Force communications in the combat environment.

The MIT team's critical breakthrough led to the use of correct digital algorithms that improved on the existing analog methods. The key to the breakthrough was the use of digital feedback through formulating and solving a stochastic (involving random variables) optimal control problem "on the fly." A minimizing choice of a loudspeaker (headphone) had to be found based on the microphone

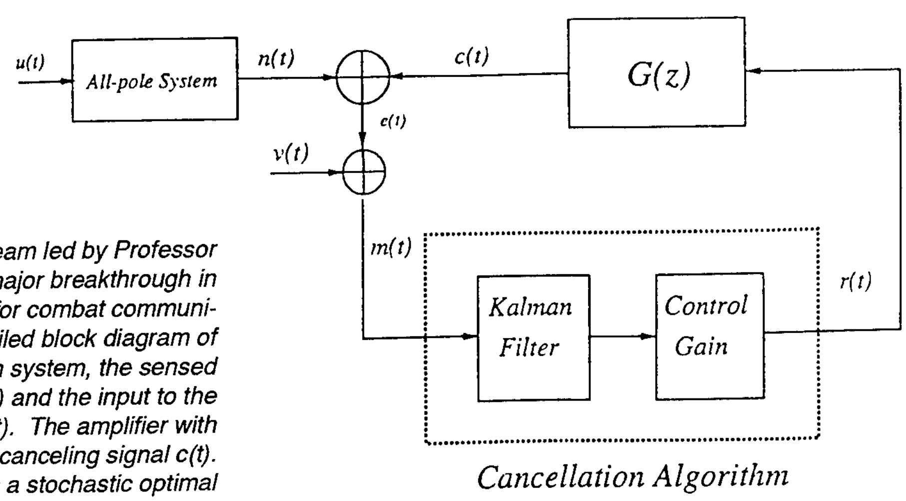

Figure 18. An MIT research team led by Professor Alan Oppenheim achieved a major breakthrough in noise cancellation technology for combat communications technology. In this detailed block diagram of the team's noise cancellation system, the sensed output at the microphone is m(t) and the input to the canceling loudspeaker is r(t). The amplifier with transfer at G(z) produces the canceling signal c(t). The cancellation algorithm is a stochastic optimal controller consisting of a Kalman filter state estimator and a variable gain component obtained through iteration on a Ricatti difference equation.

input (surrounding noise). The team obtained optimal state estimates of the loudspeaker output by using a Kalman filter together with an amplification element whose gain was computed through an interaction of a "Ricatti" (a standard formulation in control theory) equation.

Oppenheim's group performed extensive experimentation using commercial, off-the-shelf hardware components and modified headphones supplied by BOSE, Inc. The results showed that noise attenuation of 26 decibels (dB) was consistently achieved, a more than 15-fold noise-power reduction. This was a significant improvement over the analog standard of 16dB attenuation. BOSE will incorporate this hardware/firmware system into its next generation of headphones for Army and Air force use.

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Mathematician's Improved Algorithm May Benefit USAF Aging Aircraft Fleet

Dr. Michael Vogelius of the Rutgers University Mathematics Department has identified a significantly improved algorithm which improves data interpretation in the Electrical Impedance Tomography (EIT) procedure used to identify cracks in aircraft. His successful work holds great promise for application in the inspection of the Air Force's aging aircraft fleet.

EIT detects the presence of anomalies or cracks in aircraft structures from the boundary measurements of voltages induced by specified current fluxes. These current fluxes are produced by electrodes attached to the aircraft's surface. The inspection procedure uses DC current and is much safer and looks "deeper" into aircraft and other objects than X-ray tomography or eddy current methods. Vogelius' algorithm reduces the number of electrodes needed and lessens the sensitivity to measurement noise which hamper existing data interpretation schemes.

Dr. Vogelius will speak on his EIT work at the "Frontiers of Science" conference sponsored by the National Academy of Sciences in November. His research in this area has been sponsored by AFOSR for four years including the work which led to the new algorithm.

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Mathematician Develops Technique to Improve Satellite Communications

A City University of New York researcher has constructed signal processing techniques which could lead to faster and more reliable transmission of large amounts of telecommunications and surveillance data through satellite link-ups. Professor Louis Auslander of the University's Graduate

Center has developed refined wave-forming methods which will improve both speed and fidelity in Air Force and other military and civilian satellite communications. These new techniques can also be used to great advantage in military covert (low probability of intercept) communications.

Professor Auslander, in cooperation with Hughes Research in Malibu, Calif., demonstrated a modification of the standard "Costas array" frequency hopping modulation. The modification will allow better use of limited resources such as time and frequency band-width during data transmission. Satellite communication links require "spread spectrum" or wide-band methods of communication since signal concentration to a particular narrow range of frequencies can lead to its

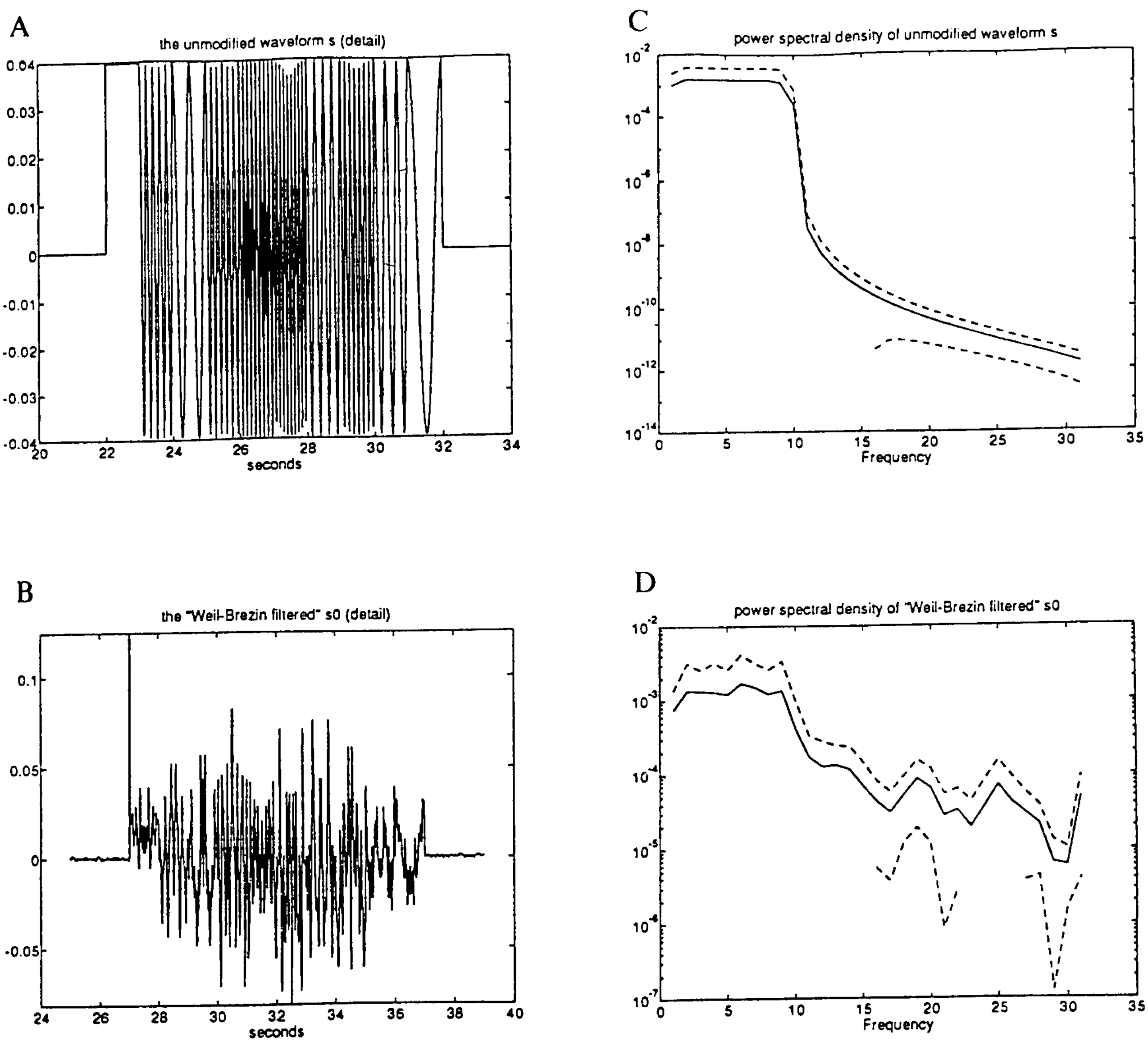

Figure 19. City University of New York researcher, Professor Louis Auslander, developed refined waveform methods to improve the speed and fidelity of satellite communications. In the figures above, an unmodified "Costas" frequency-hopped waveform is illustrated in A. Figure B represents a modification of the Costas waveform according to an operation of a Weil-Brezin transform, filtering and an inverse transform. Figure C plots the spectral density of the unmodified waveform, showing a strong concentration at low frequency. The final figure (d) shows that the modified waveform has only gradually dropped off in spectral concentration. The modified waveform better utilizes the available bandwidth and is more resistant to interference while preserving strong discrimination properties.

disruption by radio stations and other sources of interference. The actual frequency employed at any one time in satellite communication is made to "hop," spreading the signal's energy over the spectrum.

In response to a key initial insight, Auslander performed mathematical operations in "Weil space" instead of the time or frequency domain. This sophisticated mathematical analysis makes possible a series of algorithms and permits an effective treatment of several engineering concerns. A reduction in signal width allows the transmission of more signals. "Flattening the spectrum" allows full use of the available frequency band. The algorithms also account for the ambiguity function (a measure of the rate of possible errors) which keeps the incidence of erroneous identification of the encoded message to a minimum.

Hughes has adopted the techniques and is currently testing and updating them for use in satellite-linked communications

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Research Leads to Interim Protective Guidelines for Microwave Exposure

While conducting research supported by AFOSR on electromagnetic wave propagation, a University of Vermont mathematician/electrical engineer discovered the presence of a previously unknown phenomenon important to Air Force personnel working with high-power microwave systems. Using the theoretical discovery of Dr. Kurt Oughstun, the Human Systems Center (HSC) issued more stringent, interim guidelines to protect Air Force electronics engineers and technicians who work in close proximity to high-power microwave systems.

Oughstun's theoretical work clearly indicated that when an ultrashort electromagnetic pulse "impinges" on dispersive media (ranging from ceramics to human tissue) it resolves itself into a deeply penetrating component known as a precursor. Dr. Oughstun demonstrated the power content of the precursor would be much larger than previously thought possible, posing potential medical risk to personnel exposed to these special electromagnetic pulses. The precursor is essentially the leading edge of an electromagnetic field when it penetrates media. Under the direction of Dr. Richard Albanese, chief of Armstrong Laboratory's (AL) Mathematical Products Division, AL physicists simultaneously studied the phenomenon in a collaborative effort with AFOSR. Using different research methods, the researchers experimentally verified Oughstun's work.

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New Computer Model Improves Turbulence Assessment for Airborne Laser

Dr. Edmond Dewan and his fellow researchers at Phillips Laboratory's Geophysics Directorate (Hanscom, AFB) developed a new computer model to estimate optical turbulence conditions. The model will allow the Air Force to rapidly and accurately assess the operational capability of the Airborne Laser System (ABL) for theater missile defense. Phillips Laboratory is currently using it to develop system specifications for the ABL.

Understanding the worldwide seasonal distribution of upper tropospheric and stratospheric turbulence is of critical concern to the Air Force. Accurate information concerning the variability of atmospheric turbulence is needed to develop system specifications and to deploy the ABL. To obtain this information, the researchers developed a model which converts known measurements of temperature, pressure and wind velocity directly into turbulence parameters. The parameters are then used in model simulations to assess mission performance.

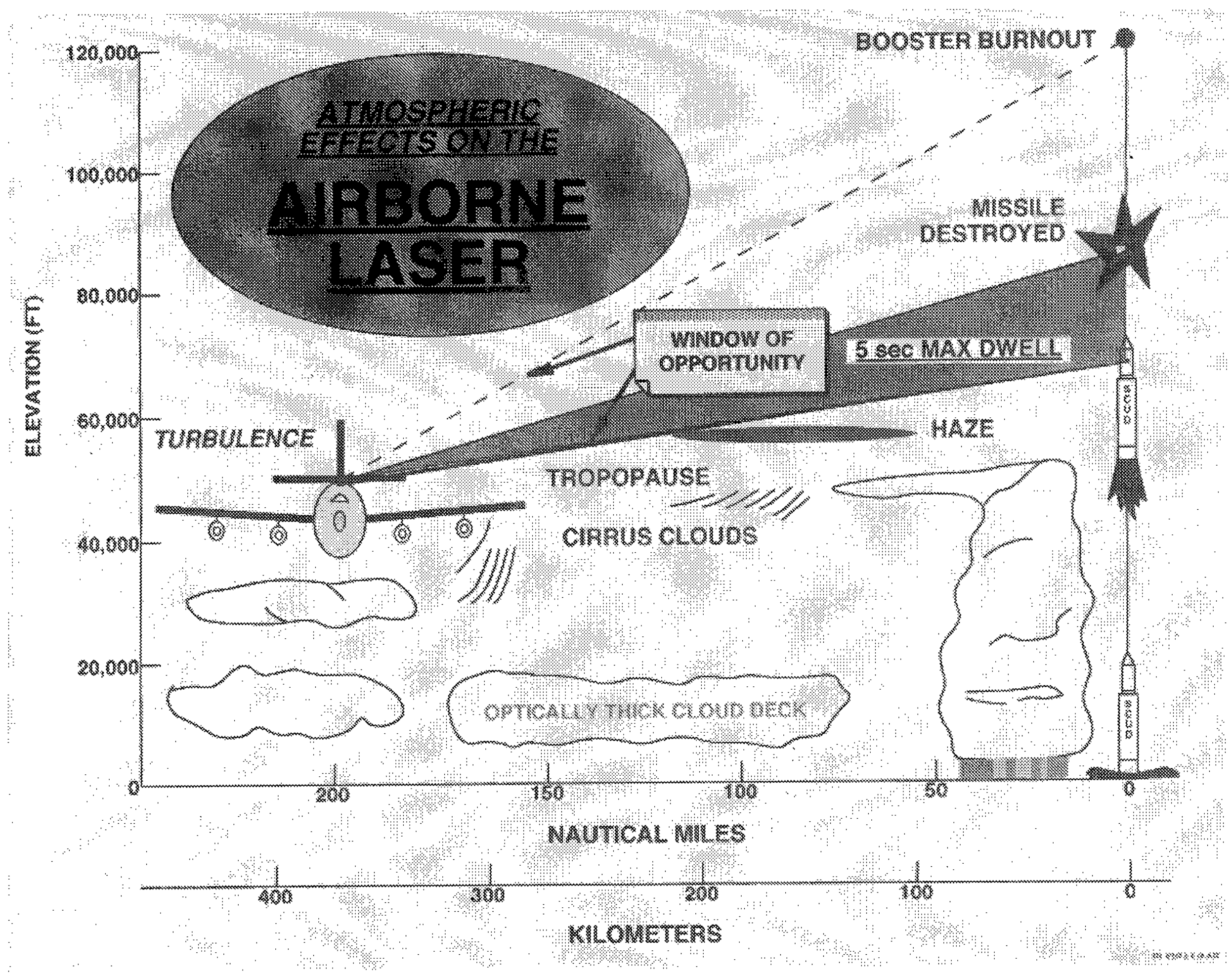

Figure 20. Edmond Dewan and researchers at the Phillips Laboratory's Geophysics Directorate developed a computer model to estimate the effects of atmospheric turbulence on the Airborne Laser System (ABL). Figure 20 is an artist's conception of some of the atmospheric effects on the ABL.

The new model is a significant improvement over previous methods of estimating optical turbulence. It is ten times faster than the existing methods and does not have to be adjusted to account for regional atmospheric characteristics. This means it can be applied worldwide, a necessary characteristic to support the ABL program. The ABL is designed as a theater ballistic missile defense "anti-scud" system which can be deployed globally.

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Multi-Target Tracking Algorithm Can Improve Radar Performance

An AFOSR researcher has developed mathematical algorithms to automatically assign targets to multiple radar tracks. Rome Laboratory is evaluating the algorithm for inclusion in the AWACS system. If this development is incorporated, it would alleviate a large part of the AWACS E-3B Sentry mission specialists' current workloads which involves the manual connection of "broken" tracks. Loral Federal Systems Company is working with the algorithms' creator, Professor Aubrey Poore of Colorado State University, to develop software with the potential to automate a portion of the AWACS system.

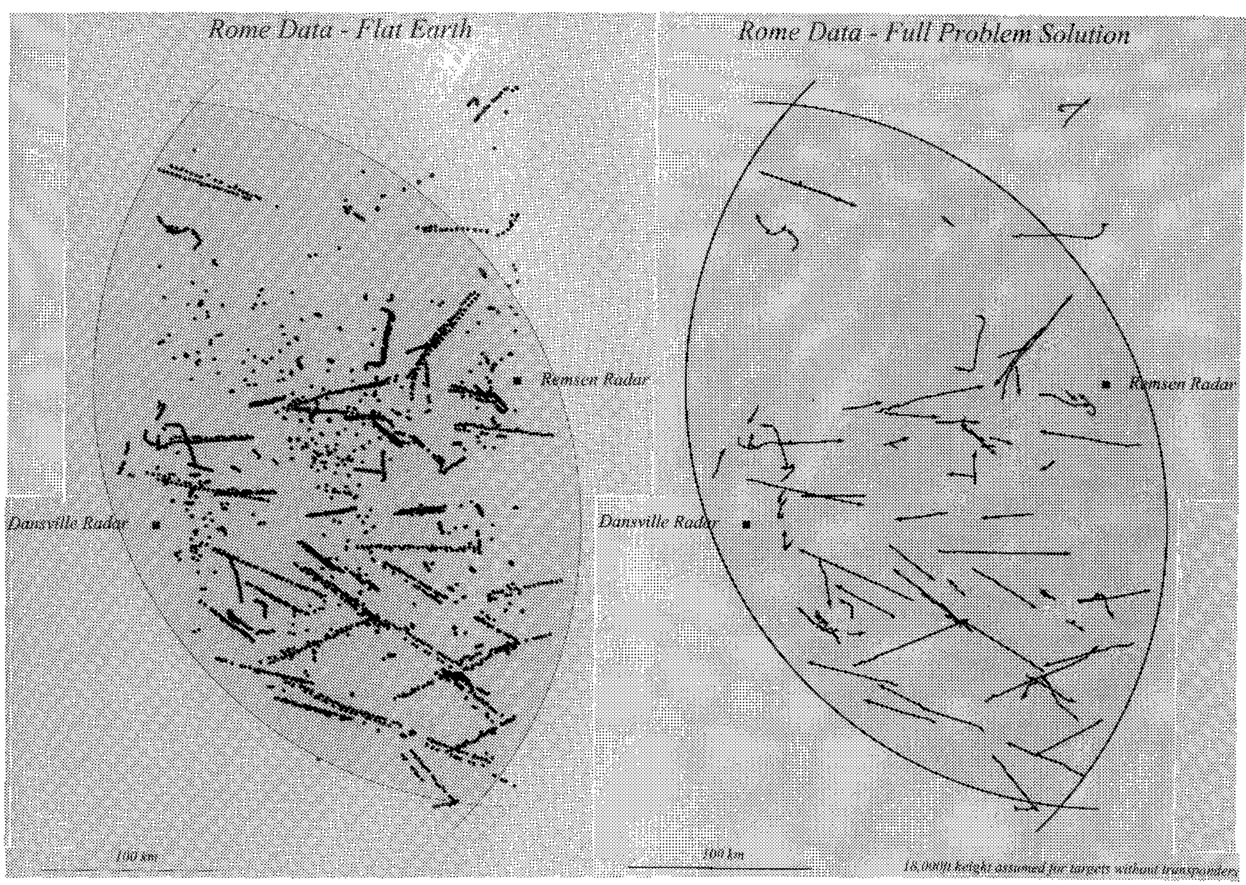

Figure 21. The figures above are taken from two radars used by Rome laboratory. The presentation at the left shows the unaligned and unconnected data from the two radars. The figure on the right shows the radar presentation after applying Professor Poore's algorithm. This fusion of data allows operators to track maneuvering targets much easier

As the number of "partial" tracks that have to be connected grows, the problem of producing an optimal set of connections increases so rapidly that an exhaustive search of all the possibilities becomes impossible. This problem is further compounded by "real-world" considerations such as spurious signals and misaligned sensors. Professor Poore's algorithm achieves "near" optimal connections in real-time. By settling for solutions which are nearly but not exactly optimal, he converted a computationally intractable problem to one that can be solved by Air Force systems.

Scientists at the Rome Laboratory Surveillance Facility are installing and testing an extension of Poore's algorithm in software. Professor Poore believes that the incorporation of automatic multi-target tracking in some Air Force radars could provide a virtual three decibel increase in power. Increasing a radar's power normally adds to its weight, but by using Poore's algorithm the Air Force could build higher performance radars with no increase in weight or maintain existing levels of performance and actually reduce weight.

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New Image Resolution Strategy Improves Target Recognition Technology

Professor Alan Willsky and his colleagues at MIT's Laboratory for Information and Decision Systems have developed a new strategy for applying multi-scale image resolution methods to improve Synthetic Aperture Radar (SAR) target identification technology. SAR technology is crucial to Air Force air-to-ground and ground-to-air tactical operations, providing 24-hour, all-weather observation with its built-in, controllable microwave illumination.

Synthetic Aperture Radar has a different physical generation mechanism and geometric structure from visible or infrared media. SAR is characterized by the creation of backscatter reflection in the local area which leads to a "salt and pepper" overlay known as "speckle." Speckle contains valuable information on the imaged scene. Professor Willsky's group applied their multi-resolution (or multi-scale) method to the differing speckle characteristics of natural and man-made scenes. The principle underlying their analysis is to separate large-grained features (coarse resolution) from small-grained features (fine resolution). The relationship between the statistics at the various levels discriminates between natural clutter (e.g. grassy fields) and man-made objects (missile launchers).

Building on this AFOSR-sponsored research, scientists in an ARPA-sponsored project at the MIT Lincoln Laboratory led by Dr. Leslie Novak significantly improved the processing of SAR images for target identification and discrimination. One of the most important goals of this research is to enable SAR to distinguish targets (man-made objects) from natural background "clutter" coming from fields or rocky terrain. In distinguishing targets, it is critical to keep the "false alarm rate" to a minimum. By applying Willsky's new algorithms, Dr. Novak's group improved the performance of the Lincoln Laboratory Target Recognition Software package. The group ultimately cut the false alarm rate in the software's "pattern matching stage" in half (from 229 mismatches to 109). They expect even better performance after gaining more experience with diverse data. These new methods perform the necessary calculations so rapidly that large areas of terrain can be quickly scanned in regions where the location of military equipment is suspected.

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Principal Investigator Develops New Aerodynamic Design Tool

Dr. Antony Jameson, the James McDonnell Distinguished Professor of Aerospace Engineering at Princeton University, has recently made major advances in the application of control theory to optimum aerodynamic shape design. The software he developed has great potential for use as a design tool to reduce the operational costs of Air Force transport aircraft. It could also dramati-

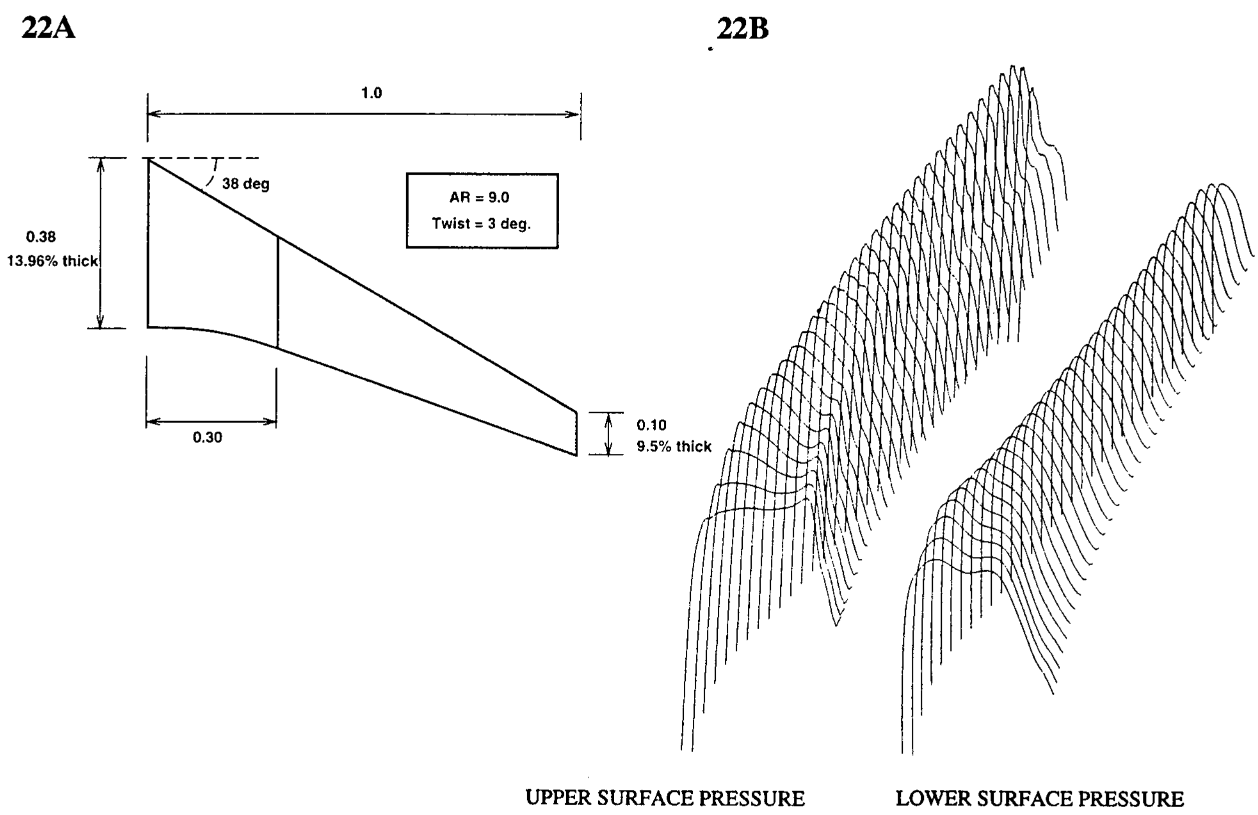

Figure 22. Professor Anthony Jameson of Princeton University has made major advances in the application of control theory to optimum aerodynamic shape design. Figure 22A illustrates the application of his method to the design of swept wings with minimum drag in the transonic regime. In this test that proved so computationally inexpensive, the wing planform shown in figure 22A was fixed, while the sections could be changed arbitrarily by the design method with a restriction on the minimum thickness and the lift coefficient forced to approach a fixed value. Figure 22B shows the computed pressure distribution on the upper surface of the wing at the design point. The wing designs resulting from these tests of Jameson's methods compared favorably to Boeing and McDonnell Douglas designs that required many man-years of work and expensive wind tunnel testing.

cally improve the affordability of new aircraft by reducing the time and effort required in the design cycle.

Jameson successfully implemented his method for three-dimensional flows modeled by the Euler equations for compressible flow. He recently applied his software to the problem of designing swept wings with minimum wave drag in the transonic regime. Using a mesh with 294,912 cells and 4,224 design variables (the surface grid), the method proved so computationally inexpensive that optimum designs can now be obtained on an IBM 530 work station in an overnight calculation. The resulting wing designs compare favorably with the best designs developed at Boeing and McDonnell Douglas which required many man-years of work and a considerable amount of expensive wind tunnel testing. To allow the treatment of more complex configurations, Jameson reformulated his method to allow for arbitrary, numerically-generated meshes. He has demonstrated this extension for two-dimensional flows and his research group is now working to develop the method for complex, three-dimensional configurations.

Following his successes in using optimization methods based on the Princeton codes to improve the Learjet wing design and the high speed civil transport (HSCT), Professor Jameson turned to corresponding problems on the Air Force's C-17 and other aircraft. The application of these optimum design methods is also the subject of a collaborative effort between Jameson's group at Princeton and the Applied Aerodynamics Division of NASA's Ames Research Center, under the direction of Dr. David Bencze, Chief of the High Speed Aerodynamics Branch. NASA's Research Institute for Advanced Computer Science (RIACS) is also participating in this work.

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Frank J. Seiler Research Laboratory

Seiler Chemists Conceive New Rechargeable Battery Concept

Chemists at AFOSR's Frank J. Seiler Research Laboratory (FJSRL) have conceived and demonstrated a new and versatile rechargeable battery concept. This major advancement in battery technology can be applied to nearly all future Air Force mission areas, particularly in space and missile applications. The new concept also holds promise to fill a growing need for high-energy, high-cycle batteries in commercial applications such as electric vehicles and high value consumer and business electronics.

The new battery concept is called the Dual Intercalating Molten Electrolyte (DIME) battery. Dr. Richard Carlin and his co-workers at FJSRL conceived it as part of a long term basic research effort in the use of molten salts for battery applications. Unlike most molten salt batteries which operate only at high temperatures, the DIME battery uses low-temperature molten salt electrolytes previously discovered at FJSRL. These novel molten salt electrolytes allow the battery to function at temperatures ranging from sub-ambient to greater than 100°C.

The DIME battery uses only inexpensive graphite or polymer-graphite composite electrode materials for both its electrodes. When the battery is charged, ions from the low temperature molten salt are inserted into both the anode and cathode electrodes. The ions are "reversibly" released during discharge. Electrodes which store energy by insertion of ions or molecules between molecular layers are termed intercalating electrodes. With the battery in this configuration, the low temperature molten salt electrolyte serves as both the source of energy storing ions and the ionic medium needed to complete the battery circuit. The chemical makeup of the low-toxicity electrolytes allows batteries to operate at high voltage (up to 4.5 volts), high power, and high cycling efficiency. These batteries also operate in a polarity switching or alternating current (AC) mode unique to modern batteries allowing them to be charged in either direction.

The Seiler research group recently published its work in the Journal of the Electrochemical Society and has submitted a patent disclosure. The group also received the AFMC Science and Technology Award for their discovery.

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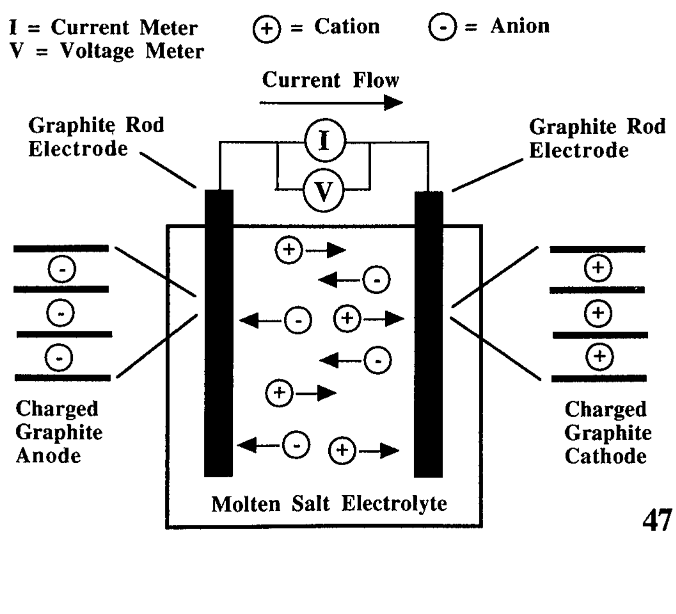

Figure 23. Illustration of DIME cell charging process. The anode and cathode graphite electrodes are shown in a charged state. During discharge, the current flow is reversed and anions and cations are removed from the graphite electrodes.

European Office of Aerospace Research and Development

Russian Nobel Laureate Visits Air Force Laboratories and Centers

Dr. Nicolai Basov, the 1964 Nobel Prize Laureate in Physics, recently completed a 17-day visit to Air Force laboratories, product centers and other organizations. Dr. Basov's visit was sponsored by AFOSR through its European Office of Aerospace Research and Development (EOARD) under the "Window on Science" program which fosters an international exchange of technical information. This education and academic program offers scientists from other countries the opportunity to visit Air Force laboratories and development organizations. Visitors typically deliver a lecture and engage in technical discussions with Air Force scientists. Dr. Basov lectured on his most recent work in laser thermonuclear hybrid reactors.

Basov's previous research led to the creation of a new branch of science and technology—quantum radiophysics. He has done extensive research on lasers since the 1950s and is considered a world-renowned expert in high-energy lasers. He is currently the Director of Russia's Institute of Quantum Radiophysics in Moscow. In addition to the Nobel Prize, he has received numerous national and international honors including the Lenin prize in 1959, several Order of Lenin awards, UNESCO's Kalinga Prize and the Edward Teller Medal.

Dr. Basov's itinerary included visits to Wright Laboratory and the Air Force Institute of Technology at Wright-Patterson AFB, Ohio; the Phillips Laboratory and the University of New Mexico in Albuquerque, N. M.; the U.S. Air Force Academy, Colorado Springs, Colo.; the Electronic Systems Center, Rome Laboratory's Electromagnetic Reliability Directorate, Phillip's Laboratory's Geophysics Directorate, and Lincoln Laboratory at Hanscom AFB, Mass.

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Chief, Chemistry and Environmental Sciences
Telephone: 44-71-514-4384

Recognition of AFOSR Researchers

AFOSR Researcher Elected to National Academy of Engineering

The National Academy of Engineering has elected Dr. Ben Freund, Professor of Engineering at Brown University, to its membership which recognizes his significant contributions to the field of solid mechanics.

For example, in collaboration with colleague Professor Michael Ortiz, under AFOSR sponsorship, he developed a new finite element/atomistic method which couples phenomena at various scales in a wide variety of material systems. This method will allow future Air Force designers to produce material systems that satisfy particular structural requirements starting at the atomic level. It also improves the understanding of deformation and failure in existing Air Force material systems, leading to improved fracture mechanics theories and life prediction methodologies.

Professor Freund's research team funded by AFOSR for the past three years is currently exploring possible applications of the new method to various solid mechanics problems. These problems include the nanoindentation (the movement of atoms due to external forces) of crystalline materials, phase transitions at crack tips in intermetallic material systems, and the effect of alloying on dislocation mobility. Professor Rob Phillips, whose background is in atomistic modeling and condensed matter physics, has recently joined the research team. His background complements the existing team members whose expertise is in solid mechanics. Dr. Owen Richmond of the Alcoa Technical Center, near Pittsburgh, is also working with the team to transition the atomistic-continuum method to problems in the metallic materials industry.

Physicist Honored at International Laser Science Meeting

Dr. John L. Hall of the University of Colorado and the National Institute of Standards and Technology received the 1993 Arthur L. Schawlow Prize at a recent International Laser Science meeting in Toronto, Canada. The award acknowledges outstanding contributions to basic research that employs lasers to advance knowledge of the fundamental physical properties of materials and their interaction with light. The prize is named for Arthur Schawlow, who shared the 1981 Nobel prize in Physics for his contribution to the development of laser spectroscopy. The award recognizes Hall "for his outstanding work in applying laser techniques to the study of quantum optics and fundamental physical constants."

Hall pioneered the development of instrumentation for laser stabilization and invented many laboratory techniques that are widely used in the laser community. His contributions include the development of FM spectroscopy, the methane stabilized He-Ne laser, high frequency servos to stabilize dye lasers, and the application of wideband electro-optic modulators in laser frequency "chirp" cooling. AFOSR has supported Hall's laser research since August 1991.

Mathematics Researcher Wins First Russian State Prize

Vladimir Zakharov, Professor of Mathematics at the University of Arizona and Director of the Landau Institute of Theoretical Physics in Moscow, was named one of the first winners of the new Russian State Prize. This award is considered the premier recognition for intellectual endeavors in modern Russia. Before the demise of the Soviet Union, the top two prizes for art, science and technology in Soviet society were the Lenin Prize and the Soviet State Prize (which Zakharov also won). These prizes have been replaced with the Russian State prize. Zakharov was recognized for his pioneering work on solitons (isolated waves that propagate without dispersion over long distances and are stable to most perturbations).

Dr. Zakharov is currently conducting research under an AFOSR grant at the University of Arizona to investigate the possible exploitation of solitons and other nonlinear wave excitations as a means of effecting communication through the plasma sheath surrounding a hypersonic vehicle. Zakharov and his fellow principal investigator, Dr. Alan Newell who chairs the University of Arizona Mathematics Department, have identified several intriguing mechanisms by which information may traverse the sheath. AFOSR has arranged for Dr. Newell to give a seminar on this subject for the Space and Missile Dynamics group at Phillips Laboratory in late January 1994.

Principal Investigator Awarded Inaugural Reid Prize

The Society of Industrial and Applied Mathematics (SIAM) bestowed the first W.T. and Idalia Reid prize on Professor Wendell Fleming of Brown University. The society created the award in honor of Professor W.T. Reid of the University of Oklahoma who was well-known for his seminal work in multidimensional problems in the calculus of variations. The Society conferred the award on Professor Fleming for his outstanding contributions to differential equations and control theory over the last 40 years. AFOSR has supported Fleming's research for the last 20 years. *His work under AFOSR auspices has led to the fundamental "underpinnings" of stochastic differential equations and optimization and control, and the application of these principles to a range of Air Force interests including the improved maneuverability of aircraft and missiles.* In addition to his own work, Professor Fleming has contributed to the national research agenda by chairing several national panels including the one which produced the influential report, "Future Directions in Control Theory "(1989).